Herring Stock Estimates from Diving Surveys of Spawn for the West Coast of Vancouver Island in 1984

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HERRING STOCK ESTIMATES FROM DIVING SURVEYS OF SPAWN FOR THE WEST COAST OF VANCOUVER ISLAND IN 1984

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ABSTRACT

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Diving surveys of spawn estimated herring stocks on the west coast of Vancouver Island, between Esperanza Inlet and Barkley Sound, at 19,710 tonnes in 1984. In two of the three Statistical Areas, Esperanza Inlet and Barkley Sound, stocks are smaller than catches in previous years. Stocks have declined throughout the study area in recent years and appear to be at a low level. Spawn was distributed shallow in Esperanza Inlet and Clayoquot Sound and deep in Barkley Sound.

Key Words: Pacific herring, spawn, diving survey, stock assessment

RESUME

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À l'aide des résultats recueillis au cours de relevés en plongée de la roque, on a calculé que les stocks de hareng sur la côte ouest de l'île Vancouver entre l'inlet Esperanza et la baie Barkley s'élevaient à 19 710 t en 1984. Dans ces deux dernières zones statistiques, les stocks sont plus petits que les prises au cours des années précédentes. Dans tout la zone expérimentale, ils ont baissé au cours des dernières années et semblent être à un faible niveau. Dans l'inlet Esperanza et la baie Clayoquot, la rogue était déposée en eaux peu profondes tandis que dans la baie Barkley, elle était fixée en eaux profondes.

Mots-clés: hareng du Pacifique, rogue, relevé en plongée, évaluation de stocks

INTRODUCTION

Herring (Clupea harengus pallasi) stocks on the west coast of Vancouver Island appear to have declined in the past four years (1981 to 1984) to levels well below those in the mid and late 1970s (Haist and Stocker 1984). Because catch expectations for roe fisheries in British Columbia are currently based on a 20% harvest rate, it is important to know with some confidence the size of the stock. Herring egg deposition can be estimated precisely by calculating the mean egg density from spawn samples collected by SCUBA divers and measuring the area of the spawn (Schweigert et al. 1985). Such a diving survey was conducted on the west coast of Vancouver Island in 1984 to determine spawner biomass except that egg density was estimated with predictive models. Time allotted to the survey did not permit a survey in Areas 26 and 27, the upper west coast of Vancouver Island. However, most of the catch, generally in excess of 95%, is taken in Areas 23 to 25, the area surveyed. The results of the diving survey is the subject of this report.

METHODS

Herring spawns were surveyed independently by Fishery Officers and SCUBA divers. Fishery Officers collected survey data using a variety of methods. Visual observations were made from the surface from a boat, frequently a viewing box was used to increase visibility of the bottom. Alternately, observations were made by snorkelling or towing a diver with snorkel behind a boat over areas where there was evidence of spawn. Grapples were used to determine the presence and obtain samples of spawn. Some of the intertidal spawn was observed at low tide while walking the beach. From these observations, the length and width of spawn and the layers of eggs were estimated (Chalmers 1984). (Additional information on spawn substrate, bare areas, etc. was also recorded but not used for this report).

The spawn survey by divers was a two-stage sampling design. Transects perpendicular to the shore were the primary sampling unit and 0.50 m^2 quadrats sampled along the transect were the secondary sampling unit. Samples consisted of all the rooted or attached vegetation, and the eggs adhering to it, within the quadrat. These samples were separated by vegetation classes (Haegele et al. 1979) into fractions, which were then weighed. A weighed subsample of fractions was preserved in 1 L jars for subsequent egg enumeration for every third sample taken. Layers of eggs, percent cover of the vegetation and dominant vegetation class were estimated by divers for each quadrat. The depth at each sample site was recorded and later corrected to Chart Datum from water levels observed at Tofino (Tides and Currents, Institute of Ocean Sciences, Sidney, B. C.) . Eggs on vegetation for each quadrat sample were estimated with a predictive model (see below) that used the diver observations and sample biomass. Eggs on the bottom substrate were estimated from diver estimates on layers of eggs and percent of bottom covered by eggs (Haegele et al. 1979) and added to eggs on vegetation.

Predictions of egg density from two models (modified from Schweigert and Fournier 1982) incorporating average layers of eggs on vegetation, vegetation class, and either the biomass of vegetation and attached eggs (biomass model), or the percent of the quadrat covered by vegetation (percent cover model) were compared to the actual egg count. The egg count was determined from the average of two estimates of total egg number that did not differ by more than 5 percent. Total egg number was determined by counting all eggs in weighed subfractions of the 1 L preserved sample. Estimates of percent cover, average layers, and biomass from surveys in Barkley Sound in 1982 (Haegele and Schweigert 1985), Georgia Strait in 1981 and 1983 (unpublished), Queen Charlotte Islands in 1981 (Haegele and Schweigert 1985), and North Coast in 1982 (Schweigert and Haegele 1984) were compared to the data from this survey to attempt to account for any discrepancies between counts and model predictions.

Transects were established at approximately equal intervals and samples were collected at equal intervals along the transect. Based on the preliminary analysis of results from studies in the Strait of Georgia, the optimal level of sampling was a transect density of 2.5 transects per km and 5 samples per transect. The average transect density for the 14 spawns sampled in this survey was 2.12 (S.D.=0.54) and on the 72 transects an average of 8.07 (S.D.=4.18) samples were taken. The mean egg density and 95% confidence interval was calculated for each spawn, each Statistical Area, and for Area 23 to 25 as a whole. Transect means were weighted by transect length to determine the overall mean (Schweigert et al. 1985a).

The inner and outer edge of spawns were determined from measurements along transects and the end of spawns beyond the outer transects were determined on exploratory dives. This information was plotted on maps of marine vegetation at scales of 1:4800 or 1:6000 (Haegele and Hamey 1977, 1979, and 1980), the boundaries of the spawn contoured, and the area of the spawn measured using an Apple graphics tablet. Spawner biomass (tonnes) was estimated as the product of spawn area, egg density, and 10^{-8}, which assumes 200 eggs$\cdot$gm^{-1} female weight (Hay 1985) and a 1:1 sex ratio.

Estimates of catch, used to determine total stock biomass, were from hailed landings reported by Fishery Officers (Chalmers 1984).

RESULTS

MODEL VALIDATION

Predicted egg numbers revealed that the predictions were substantially lower in almost all areas than densities that were observed (Table 1). The average predicted egg density (biomass model) was 274,904 eggs$\cdot$m^{-2} which was 67% of the observed mean for 161 samples. For about one half the spawns, predictions by the percent cover model were higher than by the biomass model but they were overall lower than the biomass model

predictions. There was no pattern to the differences. The predictions were about 60 percent of the observed at both high and low egg layers. Reasons for the discrepancy between observed and predicted density were not readily apparent but an examination of the data used to develop the models suggested some possibilities. Estimates of the biomass of spawn were calculated by assuming each egg weighed .00140 g. Given the egg biomass, we calculated the proportion of the total biomass comprised by spawn in each of several areas surveyed by divers from 1981 - 84 (Table 2). It was clear that most samples fell into two vegetation classes: grasses or filamentous red algae. For the grasses, where the average number of egg layers were relatively constant among areas and years, the proportion of the total sample biomass comprised by spawn was greater on the west coast of Vancouver Island than in all other areas sampled except QCI where sample size was small. It ranged from 12 to 20 percent in the Gulf and NC while reaching 24 to 30 percent on the WCVI. Results for filamentous red algae were identical. The case for the WCVI samples was less clear because the average layers of eggs was higher than for the other areas which would partially compensate for the high egg to total biomass ratio. Results for the other vegetation classes, particularly foliose reds and kelp, showed the same trend but the data was insufficient to evaluate the effect conclusively. The egg to total biomass ratios were lowest in the north coast samples which was unexpected since this area had similar average egg layers to the other areas for most vegetation classes. The same trend was evident for the average percent cover data, at least for the two main vegetation classes. For grasses, average percent cover was substantially lower for the WCVI samples in 1982 and 1984 and for Georgia Strait in 1983. Results for filamentous red algae were the same but not as pronounced. The same trends existed for the other vegetation groups but data were insufficient to evaluate the effect statistically.

BIOMASS ESTIMATES

From combined results from diver and Fishery Officer spawn surveys and from biomass model predictions of egg density, it was estimated that 13,380 tonnes of herring spawned in Statistical Areas 23 to 25 in 1984 (Table 3). Roe fisheries in 1984 harvested an additional 6330 tonnes. Total stock, therefore, was estimated at 19,710 tonnes. The 95% confidence interval for the spawner biomass estimates was within 42% of the mean.

Area 25

In Statistical Area 25 the major spawning was in Esperanza Inlet (Nuchatlitz and Port Langford) on March 5 and 6 (Fig. 1). Minor spawnings occurred in Nootka Sound (Friendly Cove) on March 25 to 29. Total spawner biomass for Area 25 was estimated at 663 tonnes, of which 647 tonnes spawned in Esperanza Inlet. Approximately 930 tonnes were harvested in the March 5 gillnet fishery in Esperanza Inlet. Hence the total stock for Area 25 was estimated at 1593 tonnes.

Nuchatlitz

Herring spawned in patches throughout the Nuchatlitz archipelago. Fishery Officers reported on 12 patches of spawn, of which 8 were surveyed by divers (Fig. 2). For these 8 patches, dimensions obtained by Fishery Officers were generally greater than those obtained by divers. Hence, Fishery Officer survey results were adjusted downward (area by 0.85) accordingly and added to diving survey results (Table 4). The total area of spawn thus determined was 47.92 ha. Egg density was low, $92 \cdot 10^3$ eggs$\cdot m^{-2}$, and the spawner biomass estimate was for 439 tonnes (Table 3).

Port Langford

Spawn was found by divers to be continuous from the western entrance to the head of Port Langford (Fig. 3). Fishery Officers reported on this spawn in 4 patches that showed the spawn to be discontinuous. It was assumed that the diving survey provided the best estimate of total spawn area at 10.65 ha (Table 4). Egg density was higher for Port Langford, at $172 \cdot 10^3$ eggs$\cdot m^{-2}$, than for Nuchatlitz and it was calculated that 183 tonnes had spawned in Port Langford (Table 3).

Friendly Cove

The late spawn in Friendly Cove was not surveyed by divers. Fishery Officers reported 1.43 ha of spawn in two patches (Table 4). Mean egg density for Esperanza Inlet ($111 \cdot 10^3$ eggs $\cdot m^{-2}$) was used to estimate spawner biomass at 16 tonnes in Friendly Cove (Table 3).

Area 24

The earliest spawn in Statistical Area 24 occurred on March 6 in Hesquiat Harbour (Fig. 4). The major spawns occurred between March 8 to 12 in lower Clayoquot Sound (Fig. 7). Late spawns occurred on March 24 in Ritchie Bay and on March 25 to 31 in Hot Springs Cove. The late spawns were not surveyed by divers but were reported by Fishery Officers. It was estimated that 7,120 tonnes spawned in Area 24 (Table 3) and there was no 1984 roe fishery here.

Hesquiat Harbour

The Hesquiat Harbour spawn was surveyed by divers but not reported by Fishery Officers (Table 5). Herring spawned on Antons Spit (Fig. 5) and at Rondeault Point (Fig. 6). Egg density was low, $52 \cdot 10^3$ eggs$\cdot m^{-2}$, and spawner biomass was estimated at 176 tonnes.

Hot Springs Cove

The spawn in Hot Springs Cove was not surveyed by divers. Fishery Officers reported on 6 small patches of spawn, a total of 672 m long (Table

5). To calculate the area of spawn, an average width of 10 m was used; average width reported by Fishery Officers was 6 m, which was considered conservative. At an egg density of $180 \cdot 10^3$ eggs$\cdot$m^{-2}, the Clayoquot Sound average, 12 tonnes of spawners were calculated for Hot Springs Cove (Table 3).

Yellow Bank

The spawn deposited on Yellow Bank (Fig. 8) was surveyed by divers on March 16 and was estimated to have been deposited on March 12 (Table 5). The Fishery Officer reported spawn to have occurred at the same location on March 24. It was assumed that both surveys referred to the same spawn and the diver survey showed 202 tonnes to have spawned at low egg density, $49 \cdot 10^3$ eggs$\cdot$m^{-2}, over a 40.80 ha area (Table 3).

McIntosh Bay

The spawn in McIntosh Bay (Fig. 9) was reported on in 8 patches by Fishery Officers, 6 of which were for the spawn inside the bay sampled on diving transect 21. The spawn outside the bay was found by divers to be extensive, while Fishery Officers reported only 2 small patches (Table 5). Egg density was high at $1024 \cdot 10^3$ eggs$\cdot$m^{-2} and 2434 tonnes were estimated to have spawned here (Table 3).

Elbow Bank

The spawn on Elbow Bank was extensive, up to 850 m wide and 3000 m long (Fig. 10). Fishery Officers reported on the spawn in 4 patches within the larger area, hence the sum of the lengths of the individual patches is greater than the total length of the spawn (Table 5). They also reported one small patch of spawn on the Vargas shore of Elbow Bank, that was not surveyed by divers. This was added to the diver estimates of area for a total of 154.11 ha of spawn. At a mean egg density of $115 \cdot 10^3$ eggs$\cdot$m^{-2}, the spawn on Elbow Bank was deposited by 1766 tonnes (Table 3).

Yarksis

The spawn at Yarksis was also extensive, up to 500 m wide and 3715 m long (Fig. 11). Fishery Officers reported on the spawn in 7 patches, underestimating area by 50% (Table 5). Egg density at Yarksis was $234 \cdot 10^3$ eggs$\cdot$m^{-2} and 1983 tonnes of herring were estimated to have spawned here (Table 3).

Saranac Island

The spawn at Saranac Island was deposited on March 24 and not surveyed by divers. Fishery Officers reported 3 patches of spawn (Table 5). Their observed lengths, the average width of spawn at nearby Robert Point as determined by divers (35 m), and the egg density for Clayoquot Sound were used to estimates spawner biomass at 21 tonnes (Table 3).

Ritchie Bay

The spawn in Ritchie Bay was reported by Fishery Officers and not surveyed by divers. Three of the 8 patches were reported to have been deposited on March 12, the remainder on March 24 (Table 5). As for Saranac Island, Fishery Officer reported lengths, average diver width for Robert Point, and average egg density for Clayoquot Sound were used to calculate spawner biomass at 100 tonnes (Table 3).

Robert Point

The spawn at Robert Point (Fig. 8) was considerably underestimated by Fishery Officers, who reported on it in 5 patches (Table 5). Divers estimated the area of spawn at 4.36 ha. The mean egg density for this spawn and the spawns at Kakawis, Opitsat, and Stubbs Island was calculated from samples obtained on transects at all 4 locations since the spawn was of similar light density (0.2 to 0.6 layers) and on the same substrate (Zostera marina) at all of them. It was estimated that 17 tonnes spawned at Robert Point (Table 3).

Kakawis

Fishery Officers reported a trace of spawn at Kakawis (Fig. 12) while divers estimated 14.16 ha (Table 5). At a mean egg density of $40 \cdot 10^3$ eggs$\cdot m^{-2}$ this spawn was deposited by 56 tonnes (Table 3).

Opitsat

The spawn at Opitsat (Fig. 12) was not reported by Fishery Officers. Divers found 18.28 ha of spawn (Table 5), which was estimated to have been deposited by 73 tonnes (Table 3).

Stubbs Island

Divers located 2 patches of spawn on Stubbs Island (Fig. 13, Table 5), which were not reported by Fishery Officers. Fifty-nine tonnes were estimated to have spawned here (Table 3).

Area 23

Herring spawned in two waves in Barkley Sound (Fig. 14) in 1984. The first wave spawned between March 13 to 18, the second wave on April 9 and 10. Only the first wave spawns were surveyed by divers. It was estimated from spawn survey results that 5723 tonnes spawned in Barkley Sound (Table 3). An additional 5400 tonnes were caught in the seine roe fishery of March 8, hence the total Barkley Sound biomass was estimated at 11,123 tonnes.

Macoah Passage

The spawn in Macoah Passage (Fig. 15) was found by divers to average 406 m wide. Fishery Officers reported this spawn to be 160 m wide and of only 0.1 layer density (Table 6). The diver survey resulted in a 1748 tonnes spawner biomass estimate and egg density was $172 \cdot 10^3$ eggs$\cdot m^{-2}$ (Table 3).

Forbes Island

Fishery Officer and diver estimates of spawn area were similar for Forbes Island (Fig. 15). However, layers of eggs were estimated by Fishery Officers to be considerably higher than estimates by divers (Table 6). At an egg density of $209 \cdot 10^3$ eggs$\cdot m^{-2}$, spawner biomass was estimated at 228 tonnes (Table 3).

Nettle Island

The spawn on Nettle and adjacent Reeks and Prideaux islands (Fig. 16) was reported on in 5 patches by Fishery Officers (Table 6). The Fishery Officer estimate of spawn width was for about one-third of the width measured by divers. This was the densest ($448 \cdot 10^3$ eggs$\cdot m^{-2}$) and major spawn in Barkley Sound with a spawner biomass estimate of 2219 tonnes (Table 3).

Maggie River

The spawn above Maggie River was not surveyed by divers (Table 6). The area of spawn as reported by Fishery Officers and the average egg density for Barkley Sound yielded a 199 tonnes spawner biomass estimate (Table 3).

SPAWN DISTRIBUTION

Spawn was deposited from +2 m (2 m above chart datum) to -6 m (6 m below chart datum) in Area 25. Percent cover of vegetation decreased with depth and it was significantly higher in the most shallow depth interval than at the deeper depth intervals (Fig. 17). Layers of eggs also decreased by depth, although the decrease was slight, from 1.5 to 0.9 layers (Fig. 17). Fifty percent of the area with spawn was above -0.7 m (Fig. 18; Table 7) and 50% of the eggs were deposited above +0.3 m (Fig. 19; Table 8). Of the 99 quadrats sampled, 82% of those with vegetation and eggs had sea grasses as the dominant vegetation, the remainder had filamentous red algae as the dominant vegetation (Table 9).

All of the egg deposition in Area 24 was in water shallower than -4 m. Percent cover of vegetation decreased with depth and differences between depth intervals were significant (Fig. 17). Layers of eggs were similar ($1.3 < \bar{x} < 1.5$) at all depth intervals (Fig. 17). Eggs$\cdot m^{-2}$, however, decreased with depth, probably because of the decrease in percent cover (Fig. 17). Fifty

percent of the area of the spawn was above -0.9 m (Fig. 18; Table 7) and 50% of the eggs were deposited above -0.7 m (Fig. 19; Table 8). Sea grasses were the dominant vegetation in 97% of the quadrats with eggs (Table 9).

Spawn in Area 23 was deposited to -16m. Percent cover was higher in the most shallow depth interval than in all the other depth intervals, where it was uniformly low ($15 < \bar{x} < 31$) (Fig. 17). Layers of eggs increased from the shallow (+2m to 0 m) to the -2 m to -4 m depth interval, from where they decreased again (Fig. 17). Eggs$\cdot m^{-2}$ followed the same trend and this pattern is similar to the one observed in 1982 in Barkley Sound (Fig. 20). However, spawn was deposited deeper in 1984 than in 1982 (Fig. 21), probably because in 1982 more of the spawn was deposited along the more gradually sloped Vancouver Island shoreline. In 1984, 50% of the spawn area was below -4.7 m and 50% of the eggs were deposited below -5.2 m. In 1982 only 11% of the area was below -4.7 m and 8% of the eggs were below -5.2 m. Of the quadrats with spawn, 69% had filamentous red algae as the dominant vegetation and 22% had kelp as the dominant vegetation (Table 9). By contrast, in 1982, only 54% of the quadrats had filamentous red algae as the dominant vegetation and 7% had kelp, while 31% had sea grasses and 7% had rockweed. The difference is probably due to the spawn being deposited deeper in 1984; grasses and rockweed generally being found in shallower water than filamentous red algae and kelp.

Barkley Sound spawner biomass in 1984 was about one-third of 1982 spawner biomass (5723 vs. 19881 tonnes). As well, length of spawn in 1984 was about one-third of length of spawn in 1982 (11.5 vs. 31.2 km) and area of spawn was similarly lower (167.9 vs 459.2 ha). Mean layers of eggs were approximately the same at 2.3 (1982) and 2.1 (1984) for all quadrats sampled and at 2.7 (1982) and 2.9 (1984) for quadrats with vegetation. However at one of the two locations where herring spawned in both years (Forbes Island) mean layers of eggs were significantly lower (Table 10). At the other location (Macoah Passage) mean layers of eggs were also lower, but not significantly.

DISCUSSION

MODEL VALIDATION

It was assumed in this study that predictive models could be used in the absence of egg counts to estimate egg density. In this survey we applied two predictive models (biomass model or model 1 and percent cover model or model 2) developed from data from several areas of the coast to data from the west coast of Vancouver Island. Although some data were available from Barkley Sound in 1982 it was unknown how representative this data was of the remainder of the WCVI. Because the predictions by both models were substantially lower than egg counts we decided to examine the data used to develop the models in more detail. In particular, the biomass of the vegetation and attached eggs was the single most important determinant in the estimate of egg density in model 1 and percent cover for model 2 (Table 1).

What was readily apparent was that some classes of vegetation both in Barkley Sound and on the WCVI as a whole were apparently different from other areas of the coast. The data indicated that vegetation was sparser on the WCVI with lower percent cover for grasses and filamentous red algae. For the grasses the vegetation biomass for 1981 and 1982 data for all but the QCI were the same but percent cover for WCVI was lower suggesting the plants may have been larger since average layers were also about equal in all areas. This was supported by the 1981 and 1983 data for Georgia Strait where percent cover has declined but so has biomass, indicating that percent cover is a reliable index of plant density. This suggests a possible explanation for the high egg biomass to total biomass ratio on the WCVI. If the plants were indeed larger on the west coast of Vancouver Island, then a given quantity of eggs would appear less dense than the same quantity on a smaller plant. This implies that egg layers would be underestimated relative to other areas with the same biomass but smaller plants so that the layers estimate would not reflect the higher egg biomass here.

At the same time, percent cover would be underestimated relative to other areas because the larger plants would be less dense but have the same surface area for egg deposition as the equivalent biomass of smaller plants in another area. The net effect would be that both models 1 and 2 should underpredict actual egg counts for data from WCVI. The same effect is confounded for filamentous red algae by different egg layers but grasses were the most important substrate on the WCVI. The high proportion of egg biomass to total biomass for WCVI can be accounted for by higher layers of eggs for some vegetation species but overall the effect is pronounced enough to suggest that there may be enough morphological or community composition differences in this area to warrant the development of a separate predictive model for this management area. There appear to be enough differences in species composition in the major management areas to warrant separate equations for each area. These area effects were not detected although tested for in the development of the prediction models (Schweigert et al. 1985b).

STOCK STATUS

The 1984 herring run to Areas 23 to 25 was estimated at 19,710 tonnes. There were also spawns in Area 27 but these were not surveyed by divers. Fishery Officers estimated the area of these spawns at 14.925 ha (Chalmers 1984). Using the average density of $214 \cdot 10^{-3}$ eggs$\cdot m^{-2}$ for Areas 23 to 25 from the diving survey (Table 3), the Area 27 stock estimates would be for 319 tonnes. Hence, the estimate for the total west coast of Vancouver Island stock from this survey was 20,029 tonnes. Given that the biomass model predicted lower than actual egg counts for the one-third of the samples counted, spawner biomass could have been greater, but would still have been within the confidence limits for estimates of spawner biomass.

In Area 25 no diving survey of spawn has been conducted prior to 1984. In 1983 Fishery Officers reported 100.92 ha of spawn and 2300 tonnes were caught in the roe fishery. In 1984, they reported 65.20 ha of spawn which was estimated from the diving survey to have been deposited by 663 tonnes. Assuming that Fishery Officer spawn survey methods were comparable

for the two years and egg density was similar, then 1026 tonnes spawned here in 1983 and the harvest rate was 69%. Stocks thus declined from 3,326 tonnes in 1983 to 1593 tonnes in 1984. A 900 tonne 1984 recruitment, assuming 45% annual natural mortality and 20% growth of repeat spawners, would account for this decline. The 10 year (1975 to 1984) average catch for Area 25 was 3920 tonnes, higher than estimated stocks in both 1983 and 1984.

A diving survey of spawn was conducted in lower Area 24 in 1979 (Haegele and Miller 1979). That survey estimated spawn at 400.28 ha. The 1984 survey estimated 361.81 ha of spawn in lower Area 24 (and 34.51 ha in upper Area 24). Egg density in 1979 was estimated at $946 \cdot 10^3$ eggs$\cdot m^{-2}$ compared to $180 \cdot 10^3$ eggs$\cdot m^{-2}$ in 1984. However, a less rigorous sampling design and a less sophisticated egg prediction model (Haegele et al. 1979) were used in the 1979 estimates. If egg density was overestimated in 1979, then the decrease in stock size is correspondingly less than the five-fold decrease otherwise indicated (40,127 tonnes in 1979 vs. 7,120 tonnes in 1984). There were no fisheries in Area 24 in 1983 and 1984, only moderate fisheries in 1979 to 1982 (average catch of 2000 tonnes), and substantial catches from 1975 to 1978 (average catch of 11,716 tonnes). In all four of those earlier years catches exceeded the total biomass estimated for 1984.

A diving survey in 1982 in Barkley Sound estimated stocks at 23,482 tonnes, of which 3600 tonnes were caught in the roe fishery and 19,882 tonnes spawned (Haegele and Schweigert 1984). Our 1984 diving survey estimated spawner biomass at 5,723 tonnes, the roe catch was 5400 tonnes, and total stocks were 11,123 tonnes. Hence, 1984 stocks were at one-half the level of 1982 stocks. In the intervening year 4627 tonnes were caught in the Barkley Sound roe fishery. Assuming 45% annual natural mortality and 20% growth, recruitments of approximately 4800 tonnes in both 1983 and 1984 would account for the decline. Roe fisheries in Barkley Sound from 1975 to 1979 took an average of 11,364 tonnes, equal to the 1984 stock level. In 1980 there was no fishery and catches from 1981 to 1984 averaged 4197 tonnes.

The evidence is that stocks have declined throughout the study area (Areas 23 to 25) in recent years and stocks appear to be at a low level which is also what population models have indicated (Haist and Stocker 1984). It would be advisable to monitor stocks on the west coast of Vancouver Island closely over the next several years to determine whether recovery is taking place.

SPAWN DISTRIBUTION AND FISHERY OFFICER SPAWN SURVEYS

Spawn in Esperanza Inlet (Nuchatlitz and Port Langford spawns) was deposited quite shallow (Table 7) and mostly on eelgrass and filamentous red algae. Estimates of spawn area by Fishery Officers were marginally higher than estimates by divers (Table 4). It appears that the techniques employed by Fishery Officers in Area 25 (grappling, viewing boxes and snorkelling) were adequate for determining the physical dimensions of these shallow spawns.

Spawn in Clayoquot Sound was also deposited quite shallow (Table 7) and almost exclusively on eelgrass. Fishery Officer estimates of spawn area

were similar to diver estimates for the mostly shallow major spawn on Elbow Bank. However, the widths and lengths of the other major and somewhat deeper spawns at McIntosh Bay and Yarksis were considerably underestimated. Overall, Fishery Officers reported about 75% of the spawn area delineated by divers (Table 5).

The area of the deeper spawns in Barkley Sound was underestimated by Fishery Officers (Table 6). The almost entirely subtidal spawn in Macoah Passage was considerably underestimated by Fishery Officers (102 ha vs. 6 ha). Fishery Officers reported about 40% of the spawn on Nettle and adjacent islands, which also was mostly subtidal on the northern side. The Fishery Officer estimate of area of the small spawn on Forbes Island slightly exceeded the diver estimates. Overall, Fishery Officers reported about 25% of the spawn area identified by divers, which was approximately equivalent to the spawn area that was shallower than 2 m below chart datum. Much of the Fishery Officer survey in Barkley Sound was done by towing a diver with snorkel behind a boat and it appears that with this technique spawn to about 2 m below chart datum can be seen. In 1982, when most of the survey by Fishery Officers was done by grappling, only 7% of the spawn area, or spawn shallower than 1.5 m above chart datum, was identified (Haegele and Schweigert 1984).

The effect that spawning stock size may have had on egg distribution in Barkley Sound is unclear because herring did not spawn in the same locations in 1982 and 1984. Herring spawned deeper in 1984, utilizing different vegetation, more kelps and less eelgrass in 1984 than in 1982. At the two locations where herring spawned in both years, mean layers of eggs were greater in 1982, but for all of Barkley Sound they were the same. Length and area of spawn were in proportion to the reduction in stock size. Hence, it would appear that the dimensions of spawns decrease as spawning stocks decrease, but whether egg density also decreases is not clear.

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Table 1. Comparison of observed and predicted egg density (eggs$\cdot m^{-2} \cdot 10^{-3}$), layers, biomass and percent cover for samples with egg counts for Areas 23 to 25.

	N	Mean egg count	Mean predicted eggs (model 1*)	Mean predicted eggs (model 2**)	Mean layers	Mean biomass (g)	Mean percent cover
Area 23							
Macoah Passage	9	101.559	80.400	131.931	2.50	546.89	23.33
Forbes Island	5	154.582	306.296	334.571	3.37	1610.40	35.60
Nettle Island	34	853.253	487.317	188.281	3.26	2887.79	23.76
Area 24							
Yellow Bank	9	79.710	42.234	78.743	0.38	407.78	48.89
McIntosh Bay	7	1931.710	1618.946	1264.533	7.68	4561.14	59.29
Meares Island	19	115.334	64.593	72.967	0.48	594.89	37.32
Yarksis	19	500.772	321.978	400.498	2.89	1518.53	44.47
Elbow Bank	21	163.742	92.449	143.880	1.15	549.29	30.71
Hesquiat Hbr.	13	67.868	72.059	37.034	0.20	967.85	43.85
Area 25							
Nuchatlitz	14	190.932	137.265	113.982	0.82	925.14	40.00
Pt. langford	11	231.181	143.350	149.803	1.02	885.64	33.64
All areas	161	411.055	274.904	214.687	1.99	1451.68	35.71

*Model 1 uses layers, vegetation type, and biomass
**Model 2 uses layers, vegetation type, and percent cover

Table 2. Estimates of the proportion of the samples comprised by spawn, average egg layers, average biomass (g), and average percent cover, by area and year (number of samples in parentheses).

	GR	EB/TB	RW	EB/TB	Kelp	FB/TB	OB	EB/TB	FOL	EB/TB	FIL	EB/TB
1981 QCI												
VB	3142	0.27	2655	0.16	1402	0.11	512	0.12	1327	0.23	780	0.18
TB	4162	(15)	3043	(11)	1629	(37)	599	(2)	1815	(4)	1050	(15)
layers	1.95		1.70		1.23		1.05		2.32		1.51	
% cover	79		54		50		83		75		45	
1981 GS												
VB	1190	0.17	595	0.08	1223	0.05	1314	0.21	913	0.15	1132	0.14
TB	1558	(135)	713	(7)	1329	(21)	1860	(40)	111	(54)	1585	(54)
layers	1.73		0.83		1.31		3.31		1.26		1.84	
% cover	69		42		52		61		52		47	
1982 NC												
VB	1382	0.12	1747	0.07	1712	0.04	1002	0.04	520	0.06	1620	0.14
TB	1703	(145)	1934	(25)	1784	(103)	1092	(8)	571	(14)	1956	(65)
layers	1.40		1.14		0.57		0.64		0.29		1.71	
% cover	62		38		64		61		35		63	
1982 WCVI												
VB	1173	0.24	1119	0.18	1697	0.21			1283	0.28	1227	0.22
TB	1809	(135)	1448	(29)	2251	(26)			1856	(3)	1660	(212)
layers	1.81		1.04		1.61				2.67		3.62	
% cover	45		33		47				55		36	
1983 GS												
VB	711	0.20	742	0.02	801	0.08	1409	0.14	764	0.17	610	0.15
TB	978	(206)	771	(18)	880	(31)	1708	(93)	983	(66)	745	(117)
layers	1.10		0.59		0.34		2.48		0.93		1.17	
% cover	45		26		27		32		36		30	
1984 WCVI												
VB	677	0.30	1985	0.11	4557	0.44			126	0.41	392	0.23
TB	1146	(109)	2218	(1)	7739	(11)			240	(2)	552	(38)
layers	1.58		0.75		3.78				1.25		2.73	
% cover	42		80		41				8		17	

TB - total biomass, EB - egg biomass (= eggs •0.0014)

GR - grasses, RW - rockweed, OB - other brown algae, FOL - foliose red algae, FIL - filamentous red alge,

VB - vegetation biomass (= TB - EB)

Table 3. Estimates of 1984 length and area of herring spawn, egg density (predicted with biomass model), and spawner biomass in Statistical Areas 23 to 25.

Area	Location	Length (m)	Area (ha)	Eggs$\cdot m^{-2} \cdot 10^{-3}$ (95% C.I.)	Tonnes of spawners (95% C.I.)
Area 25	Nuchatlitz	3269	47.92	92 (22 to 161)	439 (106 to 772)
	Port Langford	3750	10.65	172 (16 to 328)	183 (17 to 349)
	Friendly Cove	650	1.43	111 (45 to 176)	16 (6 to 25)
Total for Area 25		7669	60.00	111 (45 to 176)	663 (270 to 1057)
Area 24	Hesquiat Harbour	2600	33.85	52 (25 to 79)	176 (85 to 268)
	Hot Springs Cove	672	0.66	180 (61 to 298)	12 (4 to 20)
	Yellow Bank	1375	40.80	49 (-7 to 106)	202 (0 to 431)
	McIntosh Bay	2410	23.78	1024 (99 to 1948)	2434 (236 to 4632)
	Elbow Bank	3000	154.11	115 (24 to 205)	1766 (372 to 3160)
	Yarksis	3715	84.72	234 (103 to 365)	1983 (874 to 3091)
	Saranac Island	329	1.15	180 (61 to 298)	21 (7 to 34)
	Ritchie Bay	1587	5.54	180 (61 to 298)	100 (34 to 165)
	Robert Point	1235	4.36	40 (7 to 72)	17 (3 to 31)
	Kakawis	850	14.16	40 (7 to 72)	56 (10 to 102)
	Opitsat	800	18.28	40 (7 to 72)	73 (14 to 132)
	Stubbs Island	650	14.91	40 (7 to 72)	59 (11 to 108)
Total for Area 24		19223	396.32	180 (61 to 298)	7120 (2430 to 11810)

Table 3 (cont'd)

Area	Location	Length (m)	Area (ha)	Eggs·m^{-2}·10^{-3} (95% C.I.)	Tonnes of spawners (95% C.I.)
Area 23	Macoah Passage	2500	101.54	172 (95 to 250)	1748 (960 to 2536)
	Forbes Island	1000	10.95	209 (-148 to 565)	228 (0 to 619)
	Nettle Island	7350	49.53	448 (192 to 704)	2219 (950 to 3487)
	Maggie River	640	5.85	341 (164 to 518)	199 (96 to 303)
Total for Area 23		11490	167.87	341 (164 to 518)	5723 (2746 to 8700)
Total for Areas 23 to 25		38382	624.19	214 (125 to 304)	13380 (7779 to 18981)

Table 4. Results of 1984 herring spawn surveys by divers and fishery officers in statistical area 25.

Location	Transects	Diver			Fishery Officer			Composite	
		length (m)	av. width (m)	av. layers	length (m)	av. width (m)	av. layers	length (m)	area (ha)
Nuchatlitz	16,17	375	295	0.3	470	260	0.5	375	11.05
	(16)	175	100	0.2	170	125	0.5	175	1.75
	(16)	600	120	0.2	500	170	0.5	600	7.22
	14	250	122	1.4	120	45	0.5	250	3.06
	13,15	530	153	0.3	470	80	0.5	530	8.09
	12	550	173	0.9	800	280	0.8	550	9.52
	11	120	56	0.8	170	45	1.0	120	0.67
	10	160	117	1.1	170	20	2.5	160	1.87
	No survey	-	-	-	280	120	0.3	269	2.87
	No survey	-	-	-	70	70	1.5	67	0.42
	No survey	-	-	-	80	80	1.0	77	0.55
	No survey	-	-	-	100	100	1.0	96	0.85
	10 to 17	2760	157	0.6	3400	164	0.6	3269	47.92
Port Langford	1	150	36	0.2	120	60	1.0	150	0.54
	2 to 7	2700	29	1.3	2200	30	1.3	2700	7.71
	8	550	30	1.5	130	30	1.5	550	1.65
	9	350	21	0.1	70	30	1.5	350	0.75
	1 to 9	3750	28	1.1	2520	31	1.2	3750	10.65
Friendly Cove	No survey	-	-	-	350	15	1.5	350	0.53
	No survey	-	-	-	300	30	0.5	300	0.90
	No survey	-	-	-	650	22	0.9	650	1.43

Table 5. Results of 1984 herring spawn surveys by divers and fishery officers in statistical area 24.

Location	Transects	Diver			Fishery Officer			Composite	
		length (m)	av. width (m)	av. layers	length (m)	av. width (m)	av. layers	length (m)	area (ha)
Hesquiat Harbour	1,3	1000	130	0.21	No report			1000	24.36
	4 to 6	1600	59	0.21	No report			1600	9.49
	1,3 to 6	2600	130	0.21	No report			2600	33.85
Hot Springs Cove	No survey	-	-	-	183	9	2.0	183	0.18
	No survey	-	-	-	183	1	1.0	183	0.18
	No survey	-	-	-	32	7	(0.5)	32	0.03
	No survey	-	-	-	73	9	2	73	0.07
	No survey	-	-	-	91	9	1	91	0.09
	No survey	-	-	-	110	1	1	110	0.11
	No survey	-	-	-	672	6	1.6	672	0.66
Yellow Bank	25 to 27	1375	297	0.5	914	320	2.0	1375	40.80
McIntosh Bay	21	90	134	7.0	91	91	8.0	90	1.21
	21	100	111	7.0	91	91	10.0	100	1.55
	21	180	94	7.0	110	91	8.0	180	1.69
	21	50	30	7.0	46	14	5.0	50	0.15
	21	50	30	7.0	46	14	3.0	50	0.15
	21	230	38	7.0	46	6	4.0	230	0.88
	22	900	126	5.7	5	3	4.5	900	11.37
	23	1080	63	1.0	64	46	4.0	1080	6.78
	21 to 23	2410	99	5.7	499	63	8.0	2410	23.78
Elbow Bank	4,5	1500	325	0.3	1280	457	0.8	1500	48.80
	1 to 3	1500	610	1.4	1280	732	1.0	1500	91.55
	(2,3)	1400	80	1.7	914	91	3.0	1400	11.15
	-	183	137	-	183	14	3.0	183	2.51
	No survey	-	-	-	37	27	1.5	37	0.10
	1 to 5	3000	513	1.1	2560	640	1.0	3000	154.11

Table 5 cont'd.

Location	Transects	Diver			Fishery Officer			Composite	
		length (m)	av. width (m)	av. layers	length (m)	av. width (m)	av. layers	length (m)	area (ha)
Yarksis	12	375	166	4.3	183	91	6.0	375	6.23
	11	900	197	2.0	640	160	3.0	900	17.77
	10	350	336	1.5	274	206	2.0	350	11.76
	-	250	502	-	46	18	3.0	250	12.54
	8,9	1200	246	1.5	1006	229	3.0	1200	29.51
	7	300	104	2.3	206	91	1.0	300	3.12
	-	340	111	-	137	18	1.0	340	3.79
	7 to 12	3715	228	2.0	2492	172	2.9	3715	84.72
Saranac Island	No survey	-	-	-	137	18	6.0	137	0.48
		-	-	-	137	27	3.0	137	0.48
		-	-	-	55	9	3.0	55	0.19
		-	-	-	329	21	4.1	329	1.15
Ritchie Bay	No survey	-	-	-	37	7	1.0	37	0.13
	No survey	-	-	-	23	5	1.0	23	0.08
	No survey	-	-	-	64	14	2.0	64	0.22
	No survey	-	-	-	183	18	8.0	183	0.64
	No survey	-	-	-	64	9	6.0	64	0.22
	No survey	-	-	-	640	9	6.0	640	2.24
	No survey	-	-	-	64	2	1.0	64	0.22
	No survey	-	-	-	55	2	1.0	55	0.19
	No survey	-	-	-	457	11	5.0	457	1.60
	No survey	-	-	-	1587	10	3.9	1587	5.54
Robert Point	-	110	57	-	Trace			110	0.63
	24	200	74	0.6	73	14	2.0	200	1.48
	-	175	34	-	23	9	1.0	175	0.60
	-	300	25	-	37	14	0.5	300	0.75
	19	450	20	0.1	64	14	1.0	450	0.90
	19,24	1235	35	0.4	200	13	1.3	1235	4.36

Table 5 cont'd.

Location	Transects	Diver			Fishery Officer			Composite	
		length (m)	av. width (m)	av. layers	length (m)	av. width (m)	av. layers	length (m)	area (ha)
Kakawis	17,18	850	166	0.6	Trace			850	14.16
Opitsat	15,16	800	229	0.2	No report			800	18.28
Stubbs Island	13	450	308	0.2	No report			450	13.84
	14	200	54	0	No report			200	1.07
	13,14	650	229	0.2	No report			650	14.91

Table 6. Results of 1984 herring spawn surveys by divers and fishery officers in statistical area 23.

Location	Transects	Diver			Fishery Officer			Composite	
		length (m)	av. width (m)	av. layers	length (m)	av. width (m)	av. layers	length (m)	area (ha)
Macoah Passage	1,2,4,5	2500	406	1.5	1829	160	0.1	2500	101.54
Forbes Island	2,3	1000	110	1.8	1212	105	3.8	1000	10.95
Nettle Island	18	300	66	2.3	823	18	4.0	300	1.98
	9,10,14,16,17	2000	100	2.2	2332	18	3.5	2000	19.96
	6 to 8	1000	114	2.3	1875	23	2.8	1000	11.42
	3 to 5	1250	68	3.2	1829	18	2.0	1250	8.50
	1 to 2, 30 to 33	2800	27	1.3	2743	18	2.6	2800	7.67
	1 to 10, 14, 16 to 18, 30 to 33	7350	67	2.3	9602	19	2.9	7350	49.53
Maggie River	No survey	-	-	-	640	91	1.0	640	5.85

Table 7. Area of spawn (ha) by depth interval [m above (+) or below (-) Chart Datum] for 1984 west coast of Vancouver Island herring spawns.

Statistical Area	Location	+2 to 0	0 to -2	-2 to -4	-4 to -6	-6 to -8	-8 to 10	-10 to -16	+2 to -16
Area 25	Nuchatlitz	14.35	29.39	2.57	1.61	-	-	-	47.92
	Port Langford	0.80	6.87	2.37	0.61	-	-	-	10.65
	Friendly Cove∞	0.37	0.89	0.12	0.05	-	-	-	1.43
Total for Area 25		15.52	37.15	5.06	2.27	-	-	-	60.00
Area 24	Hesquiat Harbour	19.75	14.10	-	-	-	-	-	33.85
	Hot Springs Cove*	0.12	0.49	0.05	-	-	-	-	0.66
	Yellow Bank	1.64	39.16	-	-	-	-	-	40.80
	McIntosh Bay	-	14.81	8.97	-	-	-	-	23.78
	Elbow Bank	18.50	135.61	-	-	-	-	-	154.11
	Yarksis	17.64	51.33	15.75	-	-	-	-	84.72
	Saranac Island*	0.20	0.85	0.10	-	-	-	-	1.15
	Ritche Bay*	0.99	4.11	0.44	-	-	-	-	5.54
	Robert Point	1.98	2.38	-	-	-	-	-	4.36
	Kakawis	0.35	13.42	0.39	-	-	-	-	14.16
	Opitsat	5.82	12.46	-	-	-	-	-	18.28
	Stubbs Island	3.39	5.43	6.09	-	-	-	-	14.91
Total for Area 24		70.38	294.15	31.79	-	-	-	-	396.32
Area 23	Macoah Passage	14.19	16.61	20.28	21.13	19.91	9.24	0.18	101.54
	Forbes Island	1.08	1.56	1.71	1.84	1.83	1.42	1.51	10.95
	Nettle Island	-	2.79	9.82	13.46	12.06	7.96	3.44	49.53
	Maggie River*	0.55	0.76	1.15	1.32	1.22	0.67	0.18	5.85
Total for Area 23		15.82	21.72	32.96	37.75	35.02	19.29	5.31	167.87
Total for Areas 23 to 25		101.72	353.02	69.81	40.02	35.02	19.29	5.31	624.19

*Spawns not surveyed by divers and area by depth interval estimated

Table 8. Estimates of mean egg density from samples with egg counts and number of eggs by depth interval for 1984 herring spawns on the west coast of Vancouver Island.

Statistical Area	Depth interval	Area (ha)	N	Eggs$\cdot m^{-2} \cdot 10^{-3}$ (95% C.I.)	No. of eggs$\cdot 10^{-8}$ (95% C.I.)
Area 25	+2 to 0	15.52	3	589 (-)	914 (-)
	0 to -2	37.15	21	159 (49 to 269)	591 (182 to 999)
	-2 to -4	5.06	4	47 (-)	24 (-)
	-4 to -6	2.27	3	56 (-)	13 (-)
Area 24	+2 to 0	70.38	21	518 (26 to 1010)	3646 (183 to 7110)
	0 to -2	294.15	74	248 (124 to 372)	7295 (3647 to 10942)
	-2 to -4	31.79	12	89 (5 to 173)	283 (16 to 550)
Area 23	+2 to 0	15.82	1	421 (-)	666 (-)
	0 to -2	21.72	13	196 (89 to 304)	426 (193 to 660)
	-2 to -4	32.96	14	735 (27 to 1443)	2423 (189 to 4756)
	-4 to -6	37.75	11	1485 (-237 to 3207)	5606 (0 to 12106)
	-6 to -8	35.02	11	988 (-18 to 1834)	3460 (0 to 6423)
	-8 to -10	19.29	7	312 (-48 to 672)	602 (0 to 1296)
	-10 to -16	5.31	11	137 (-23 to 297)	73 (0 to 158)

Table 9. Number of observations on dominant vegetation type for quadrats sampled on the west coast of Vancouver Island in 1984 and in Barkley Sound (Area 23) in 1982.

Dominant vegetation	Area 25	Area 24	Area 23	
			1984	1982
Sea grasses	68	229	7	130
Rockweed	0	0	1	30
Kelp	0	1	33	28
Foliose red algae	0	0	4	4
Filamentous red algae	15	6	102	226
Bare	16	47	49	44
Total	99	283	196	462

Table 10. Comparison of observed layers of eggs in 1982 and 1984 for quadrats sampled in identical locations at Forbes Island and in Macoah Passage and for all of Barkley Sound (bare quadrats are excluded).

	1982				1984				P
Location	n	mean	(95%C.I.)	SD	n	mean	(95%C.I.)	SD	(Student -t)
Forbes Island	12	6.4	(4.0-8.8)	4.2	12	2.1	(0.5-3.7)	2.8	0.01
Macoah Passage	40	2.4	(2.0-2.8)	1.3	36	2.0	(1.5-2.4)	1.5	0.19
Barkley Sound	407	2.7	(2.4-2.9)	2.6	139	2.9	(2.5-3.3)	2.4	0.37

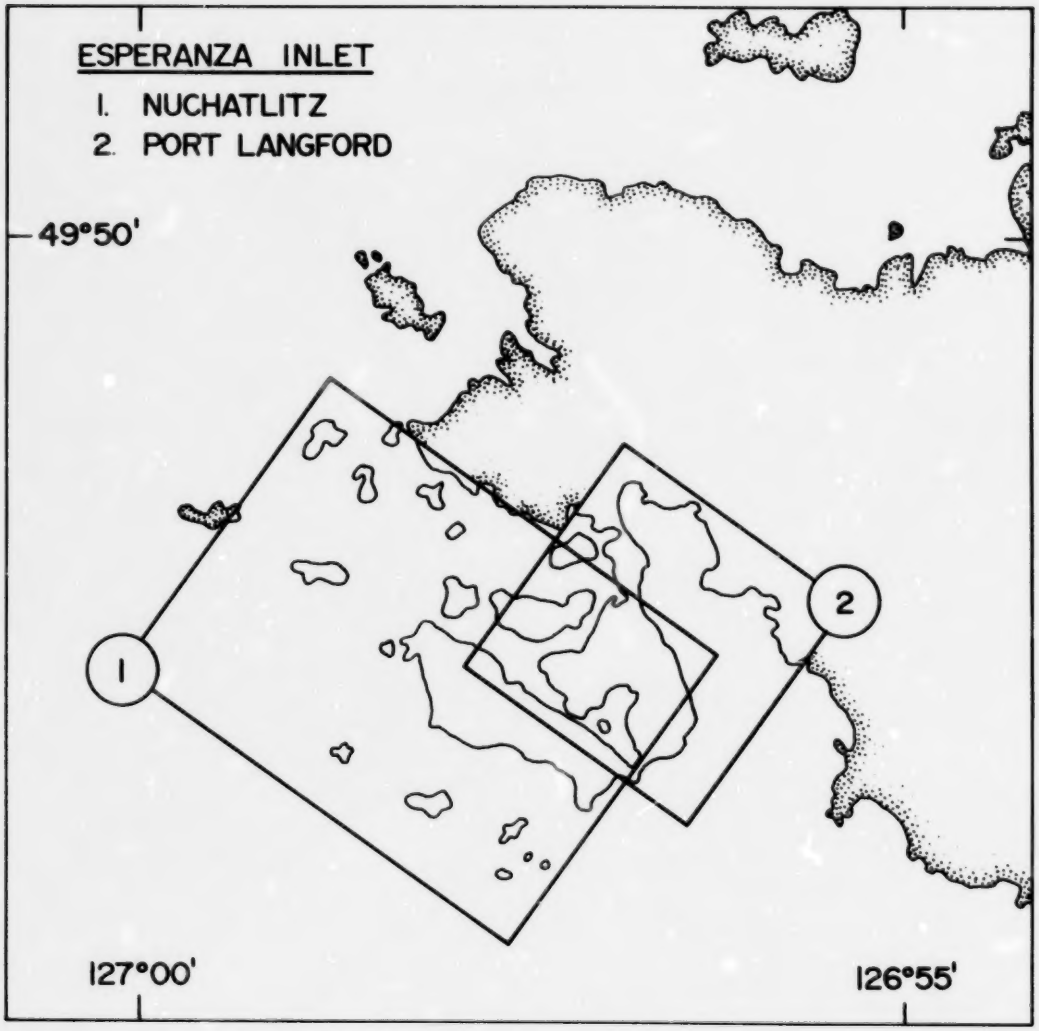
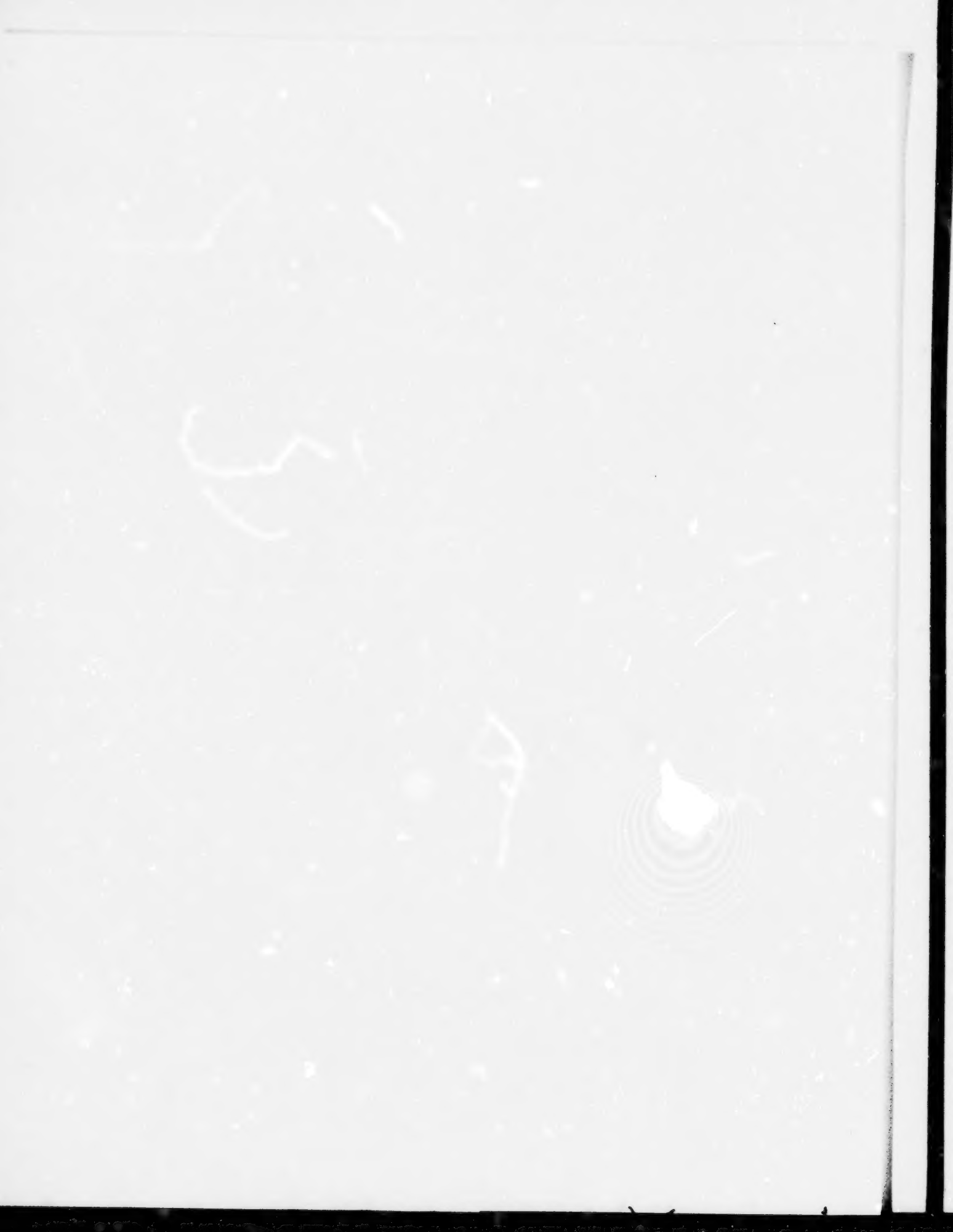


Fig. 1. Esperanza Inlet study area with boxes outlining location of spawn survey maps (Figs. 2 and 3).



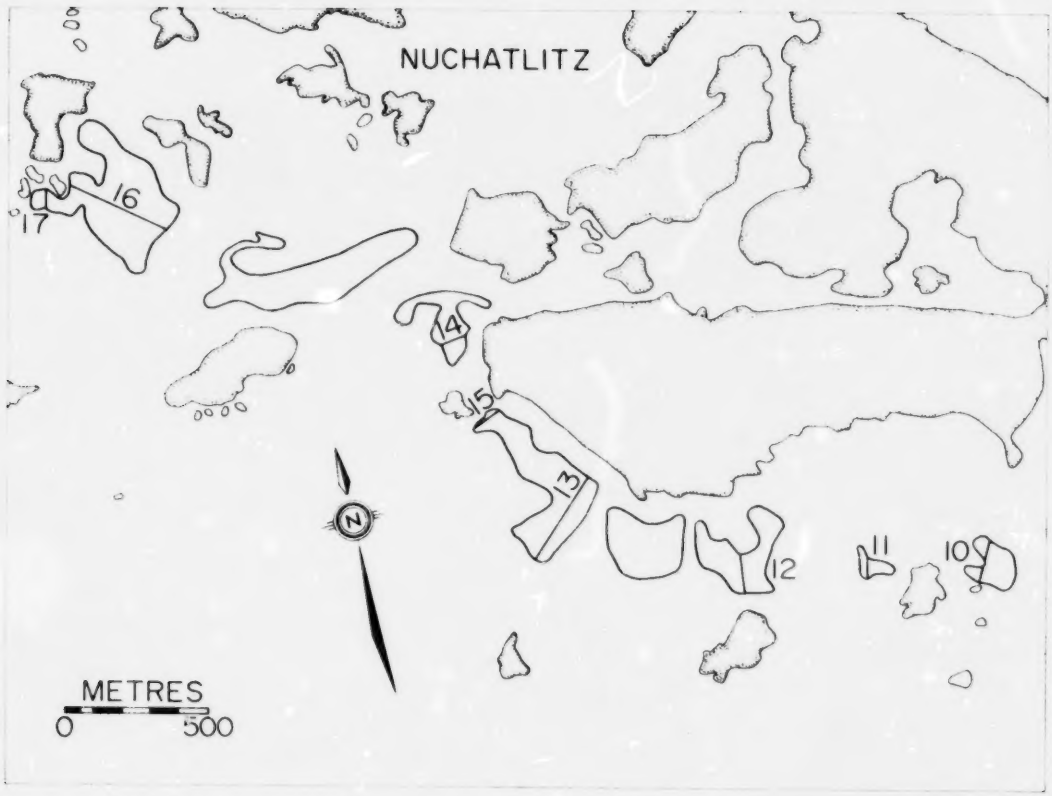


Fig. 2. Herring spawn in Nuchatlitz, surveyed by divers in 1984, with transect locations shown.

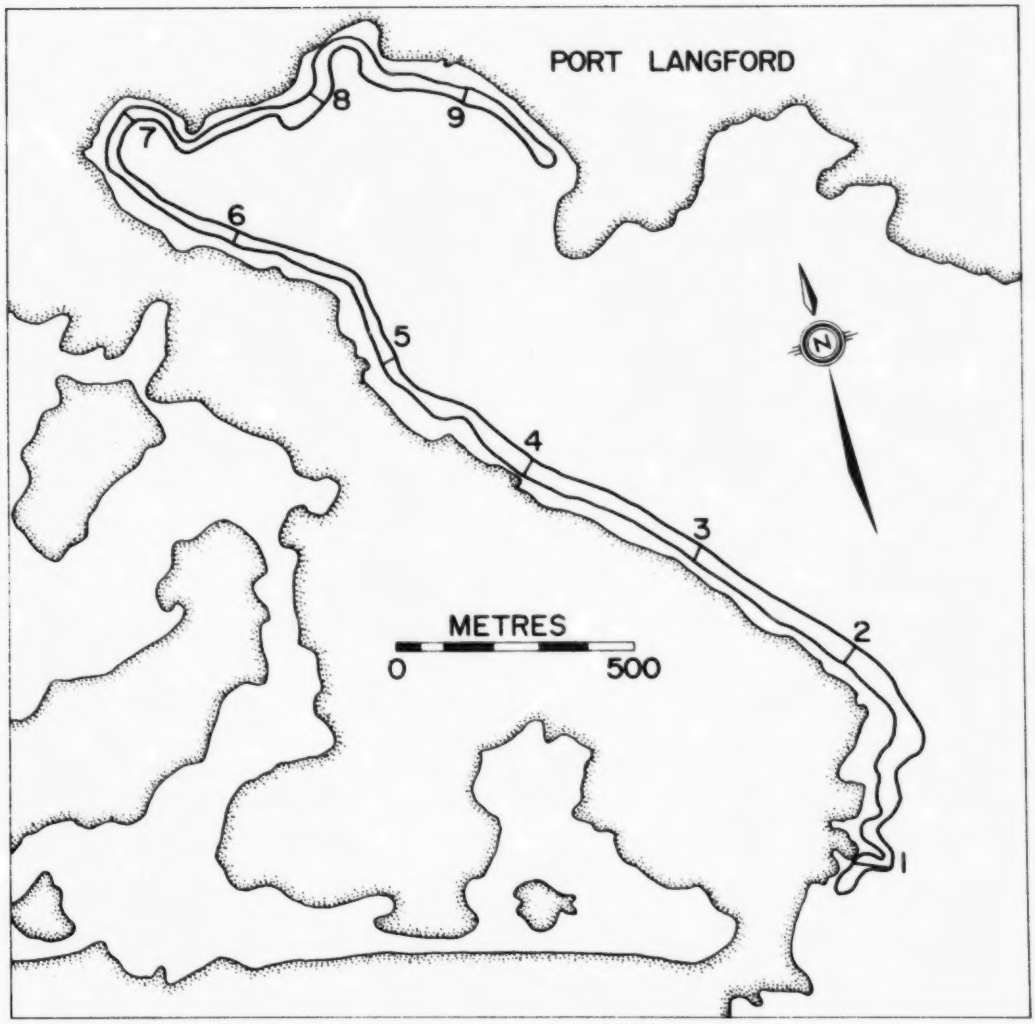


Fig. 3. Herring spawn in Port Langford, surveyed by divers in 1984, with transect locations shown.

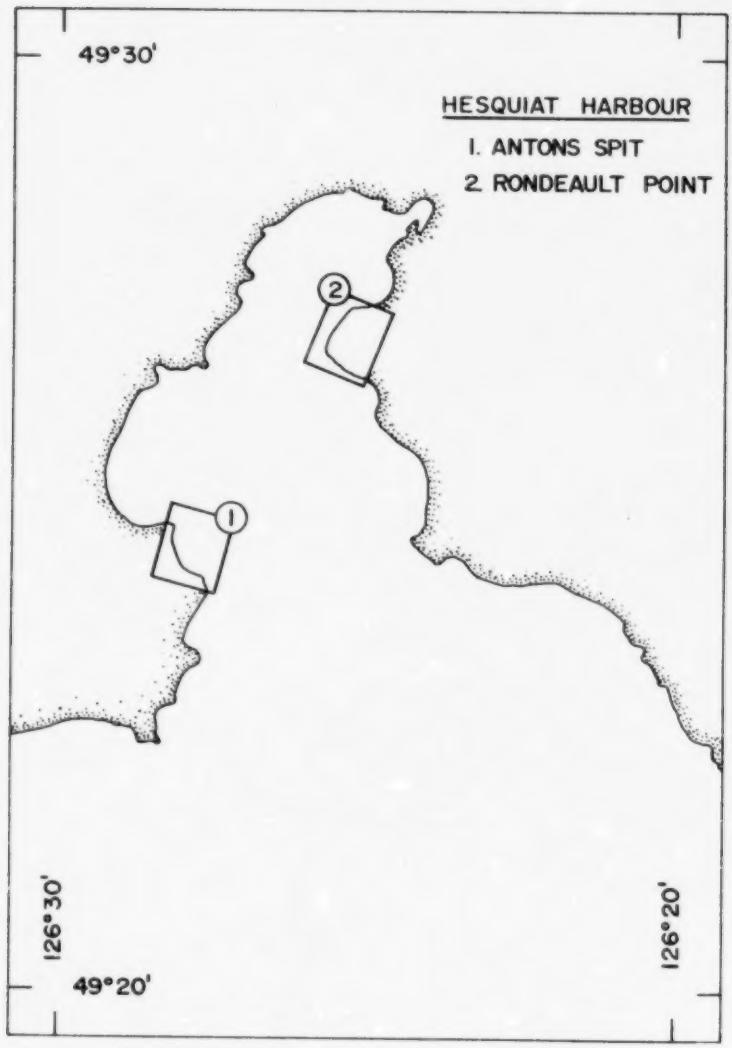


Fig. 4. Hesquiat Harbour study area with boxes outlining location of spawn survey maps (Figs. 5 and 6).

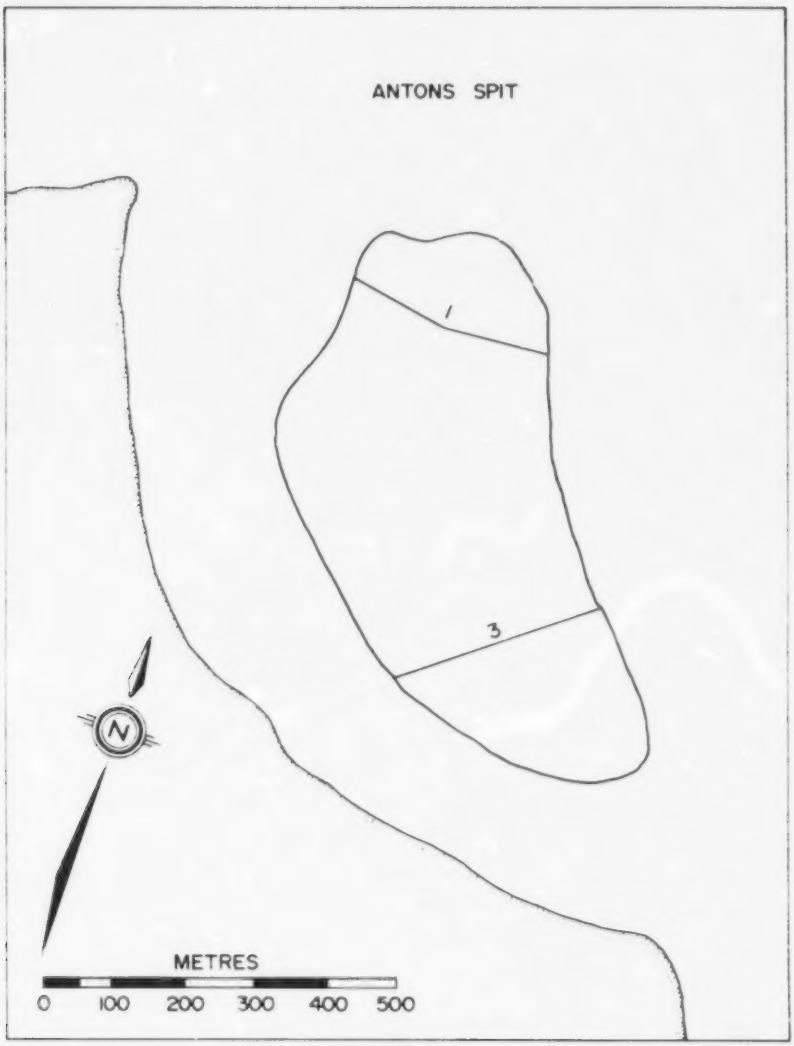


Fig. 5. Herring spawn on Antons Spit, surveyed by divers in 1984, with transect locations shown.

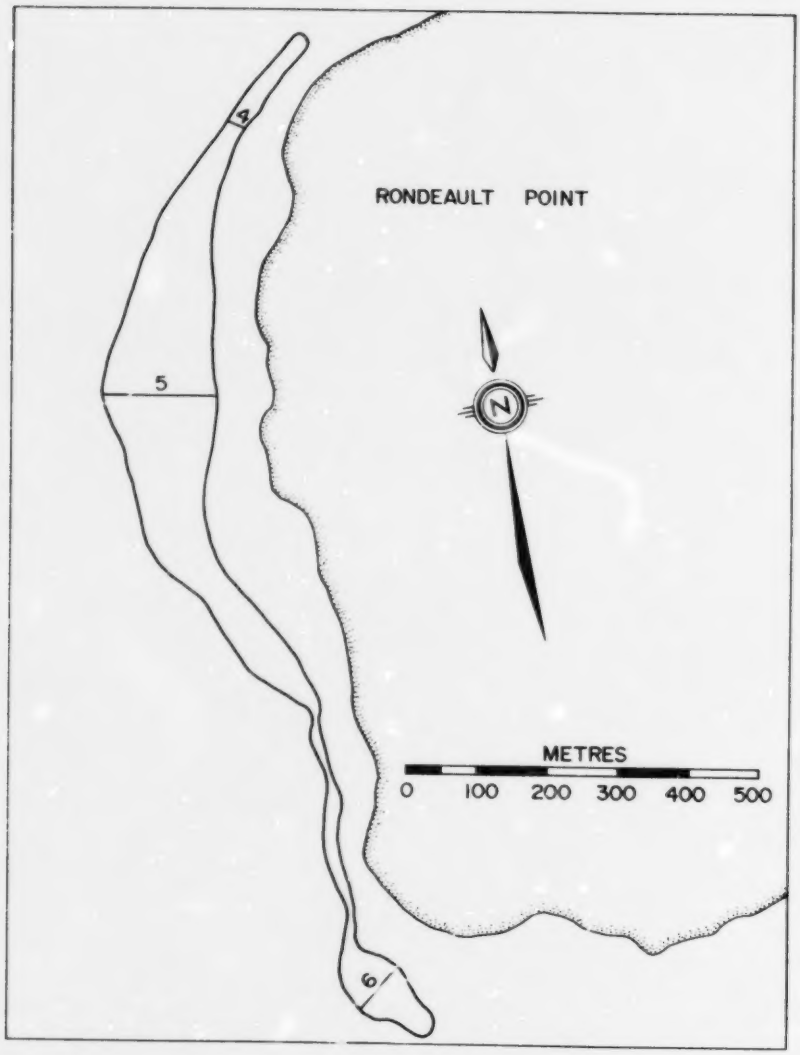


Fig. 6. Herring spawn at Rondeault Point, surveyed by divers in 1984, with transect locations shown.

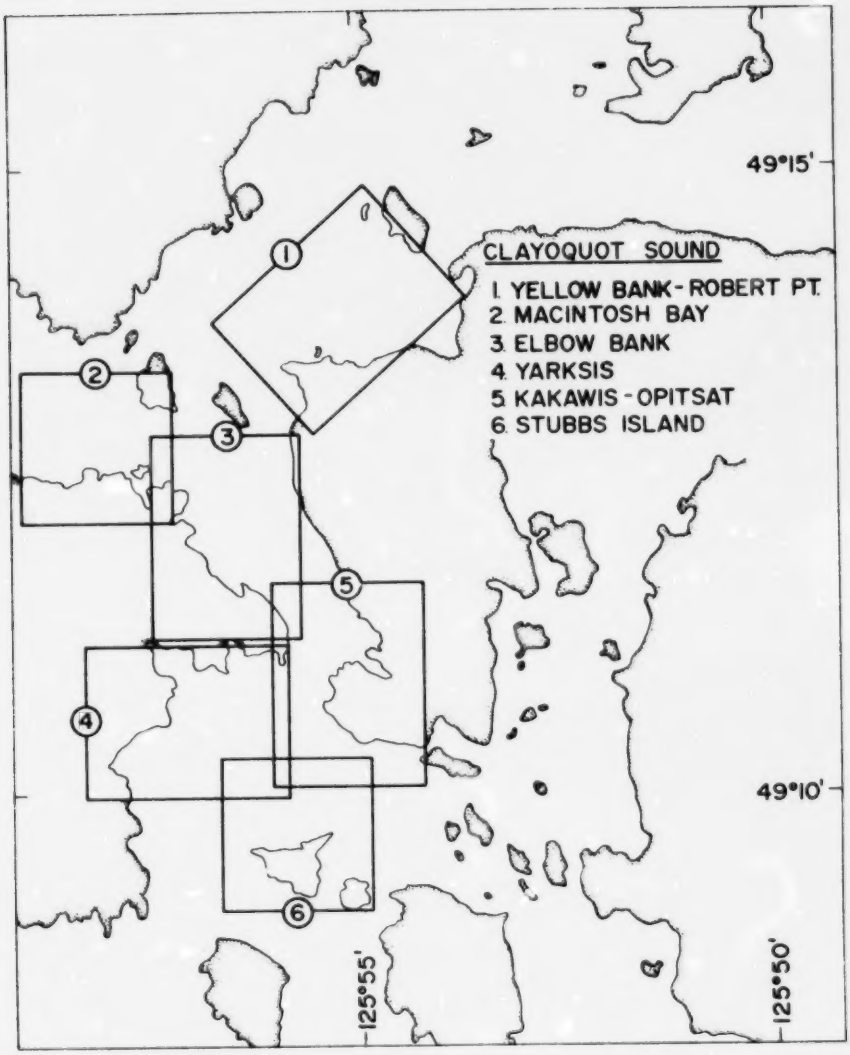


Fig. 7. Clayoquot Sound study area with boxes outlining location of spawn survey maps (Figs. 8 to 13).

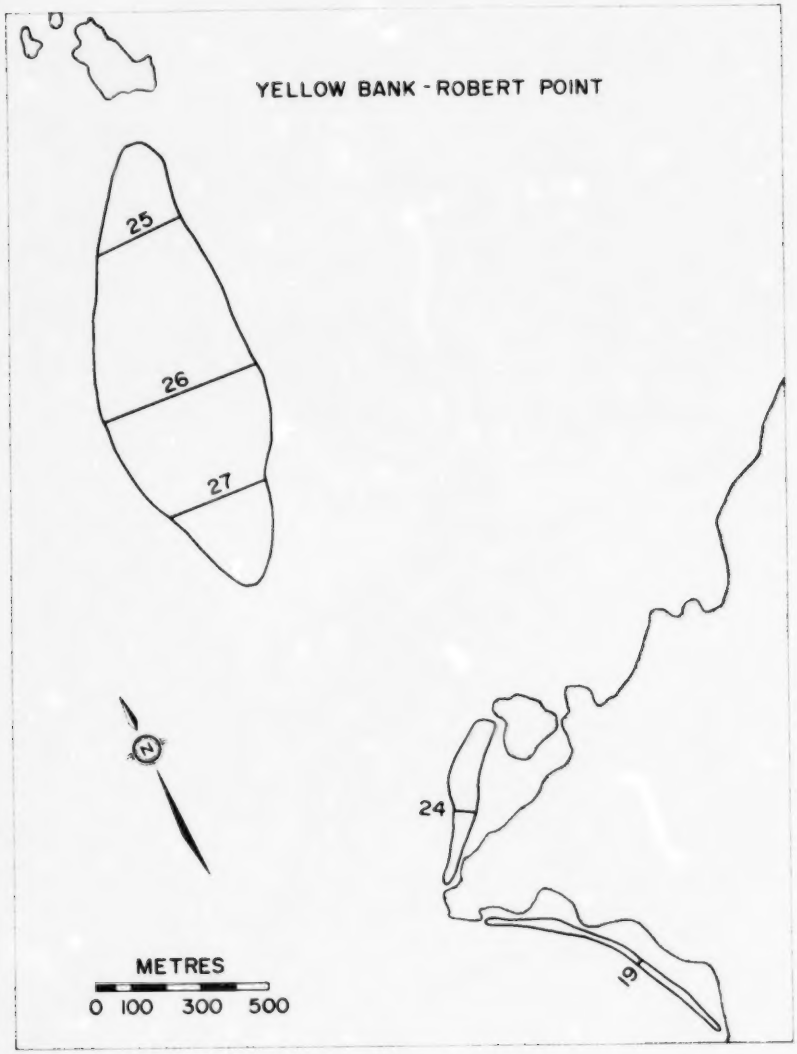


Fig. 8. Herring spawn on Yellow Bank and at Robert Point, surveyed by divers in 1984, with transect locations shown.

Fig. 9. Herring spawn in McIntosh Bay, surveyed by divers in 1984, with transect locations shown.

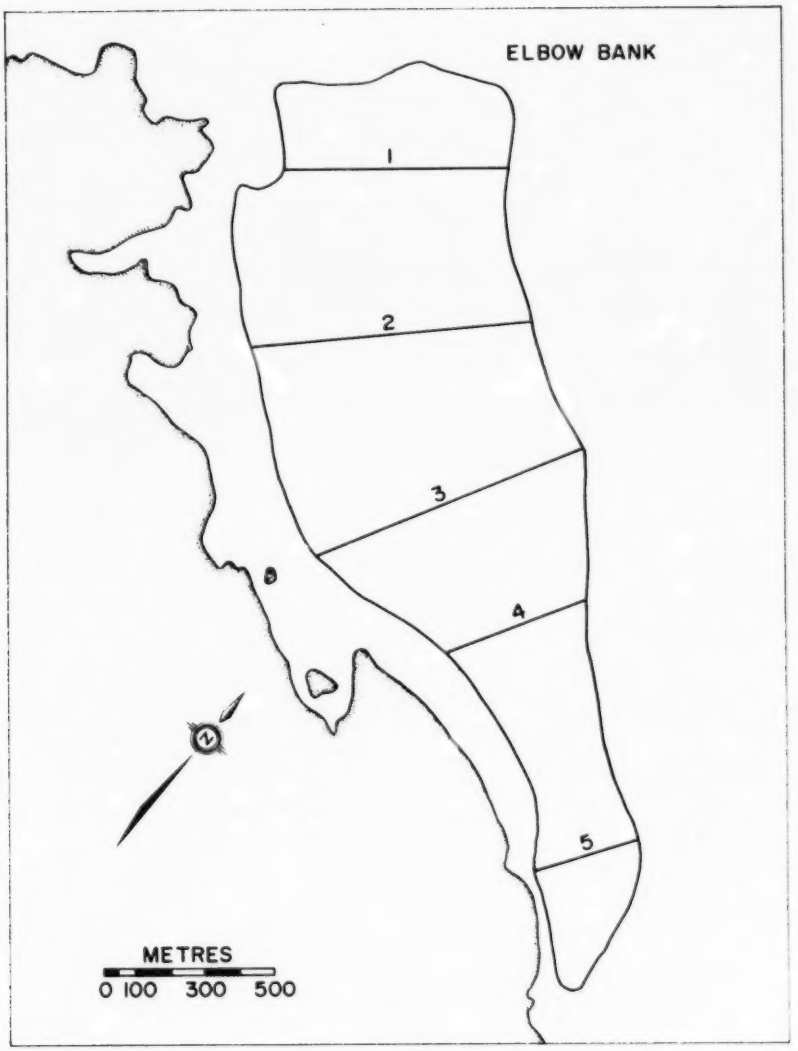


Fig. 10. Herring spawn on Elbow Bank, surveyed by divers in 1984, with transect locations shown.

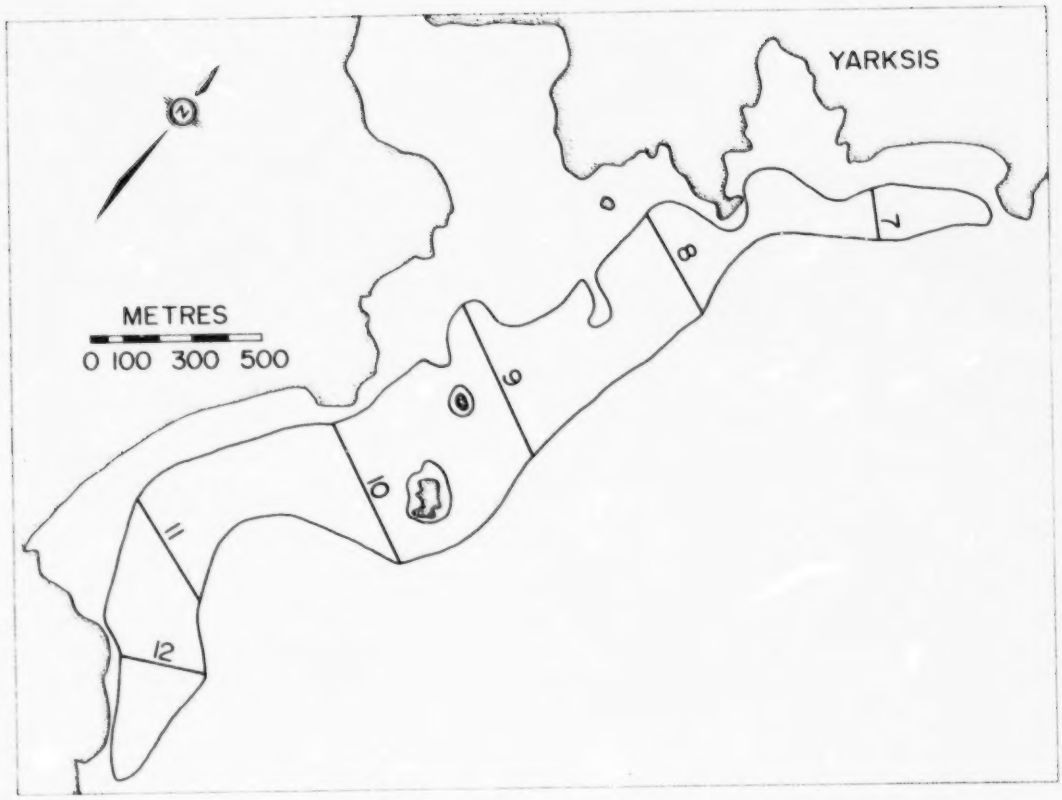


Fig. 11. Herring spawn at Yarksis, surveyed by divers in 1984, with transect locations shown.

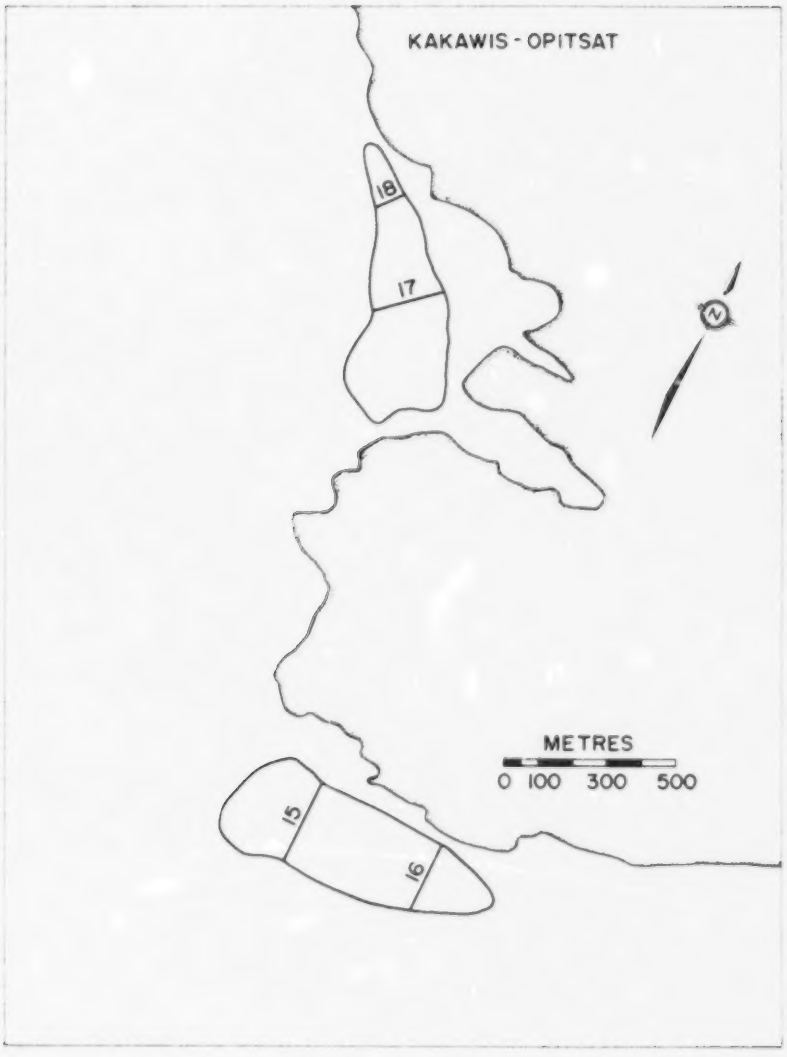


Fig. 12. Herring spawn at Kakawis and Opitsat, surveyed by divers in 1984, with transect locations shown.

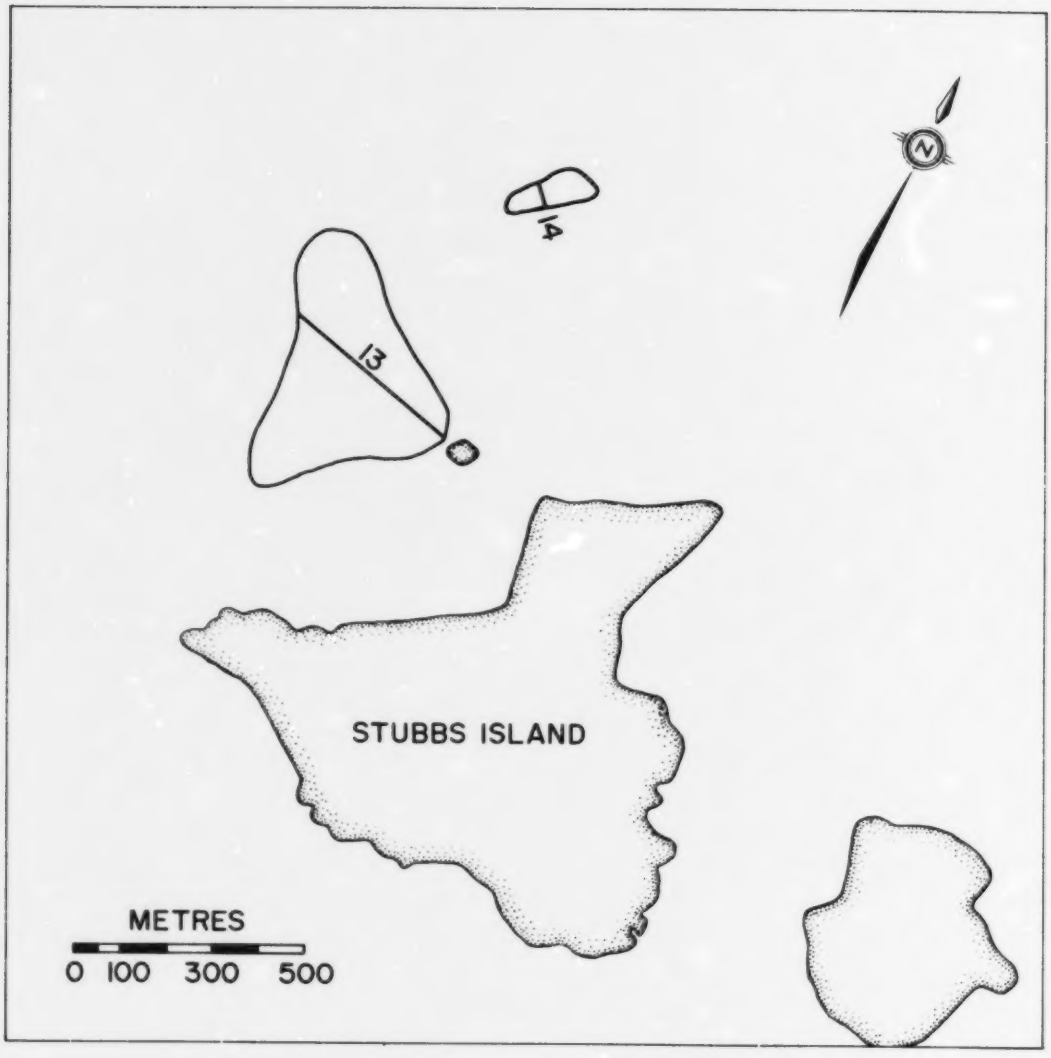


Fig. 13. Herring spawn at Stubbs Island, surveyed by divers in 1984, with transect locations shown.

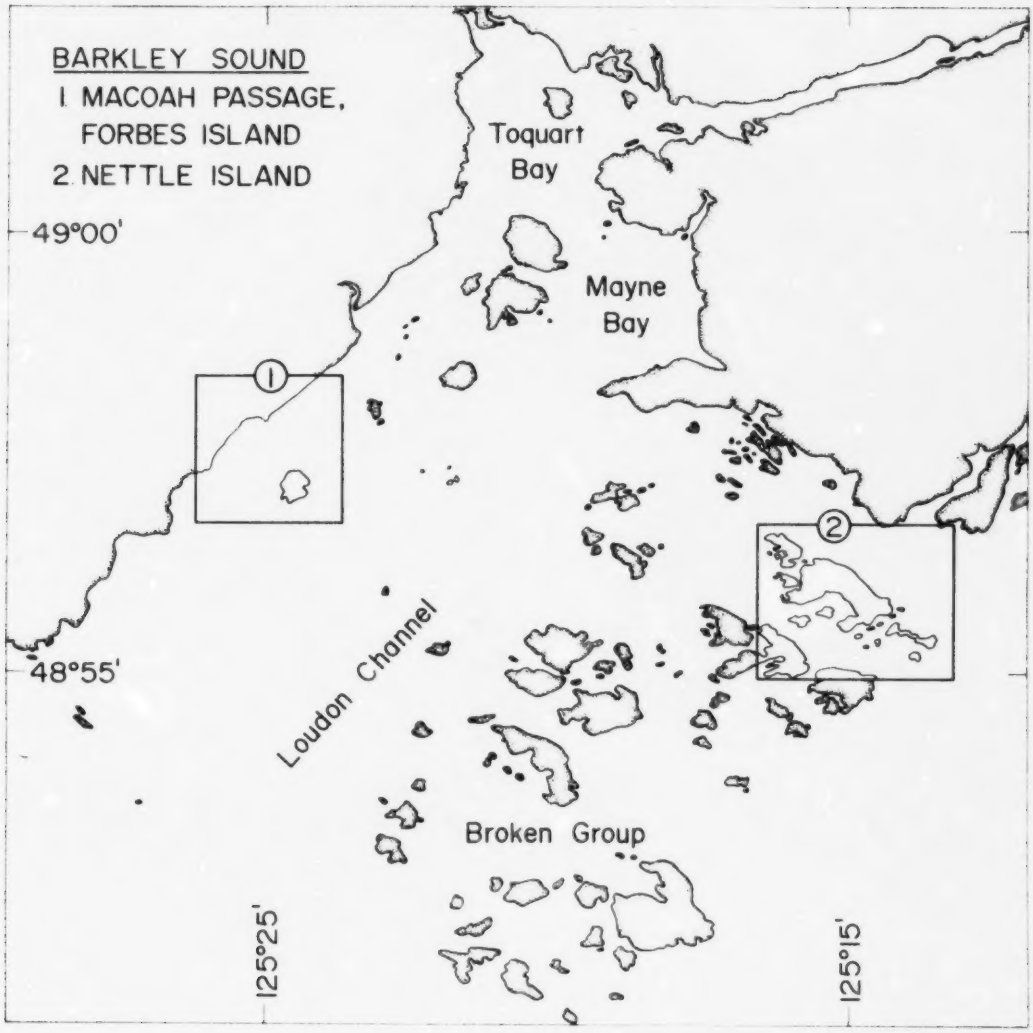


Fig. 14. Barkley Sound study area with boxes outlining location of spawn survey maps (Figs. 15 and 16).

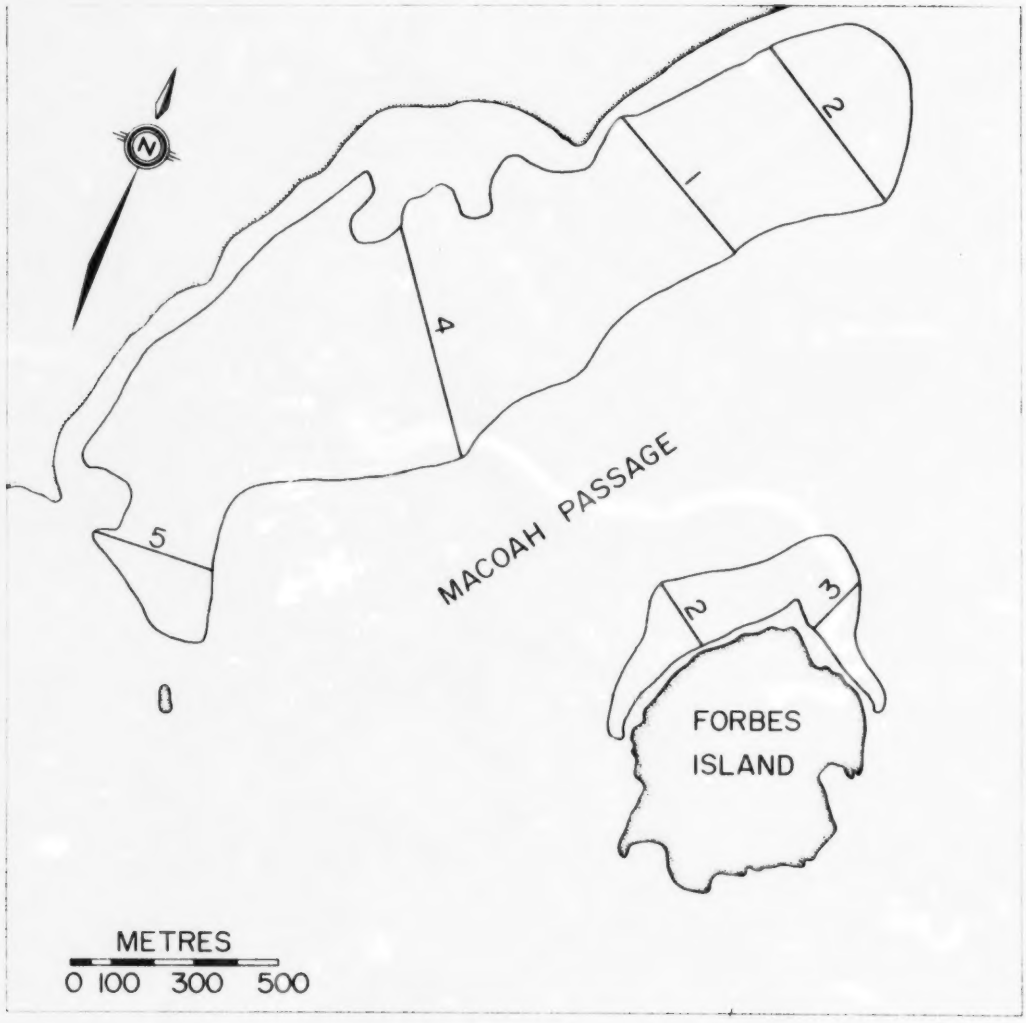


Fig. 15. Herring spawn in Macoah Passage and at Forbes Island, surveyed by divers in 1984, with transect locations shown.

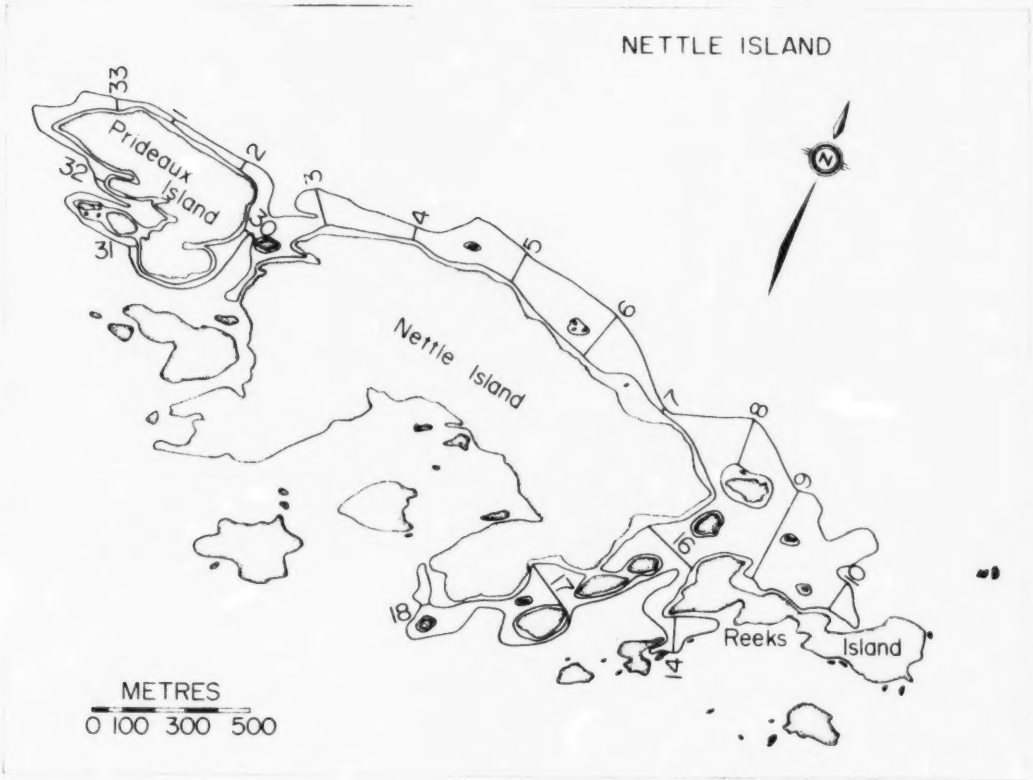


Fig. 16. Herring spawn at Nettle and adjacent islands, surveyed by divers in 1984, with transect locations shown.

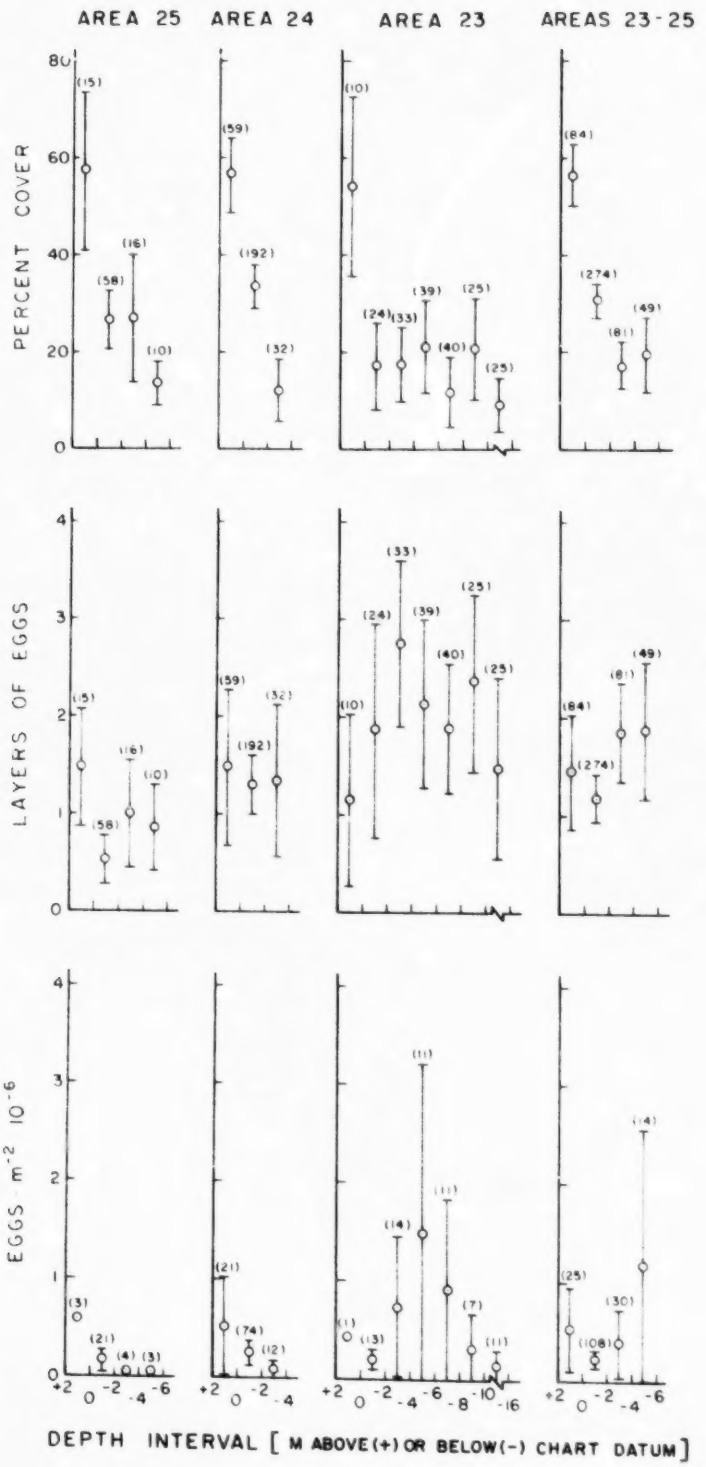


Fig. 17. Average percent cover of vegetation, layers of eggs, and egg density (± 2SE) by 2 m depth interval for 1984 herring spawns on the west coast of Vancouver Island.

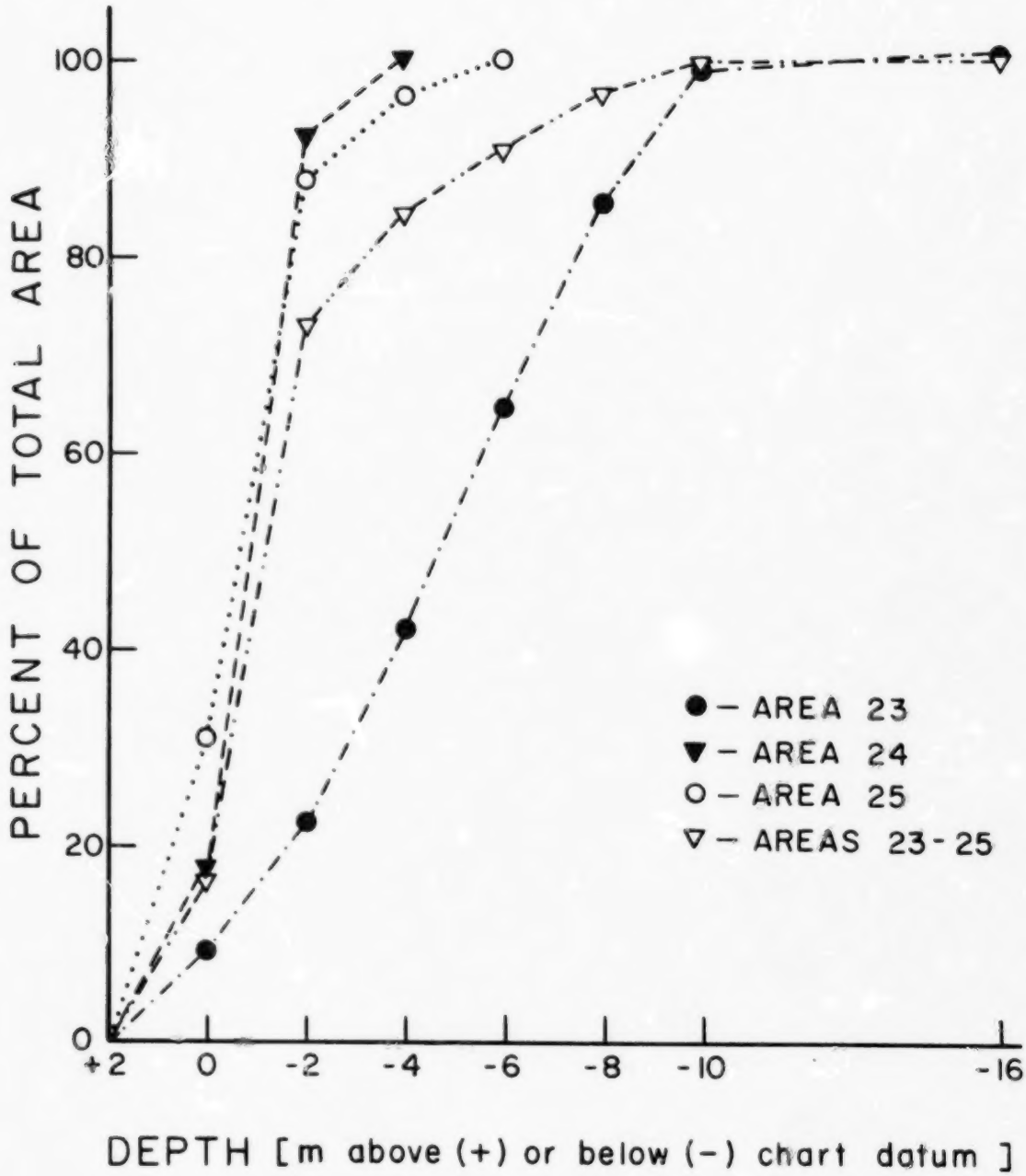


Fig. 18. Distribution of spawn area by depth on the west coast of Vancouver Island in 1984.

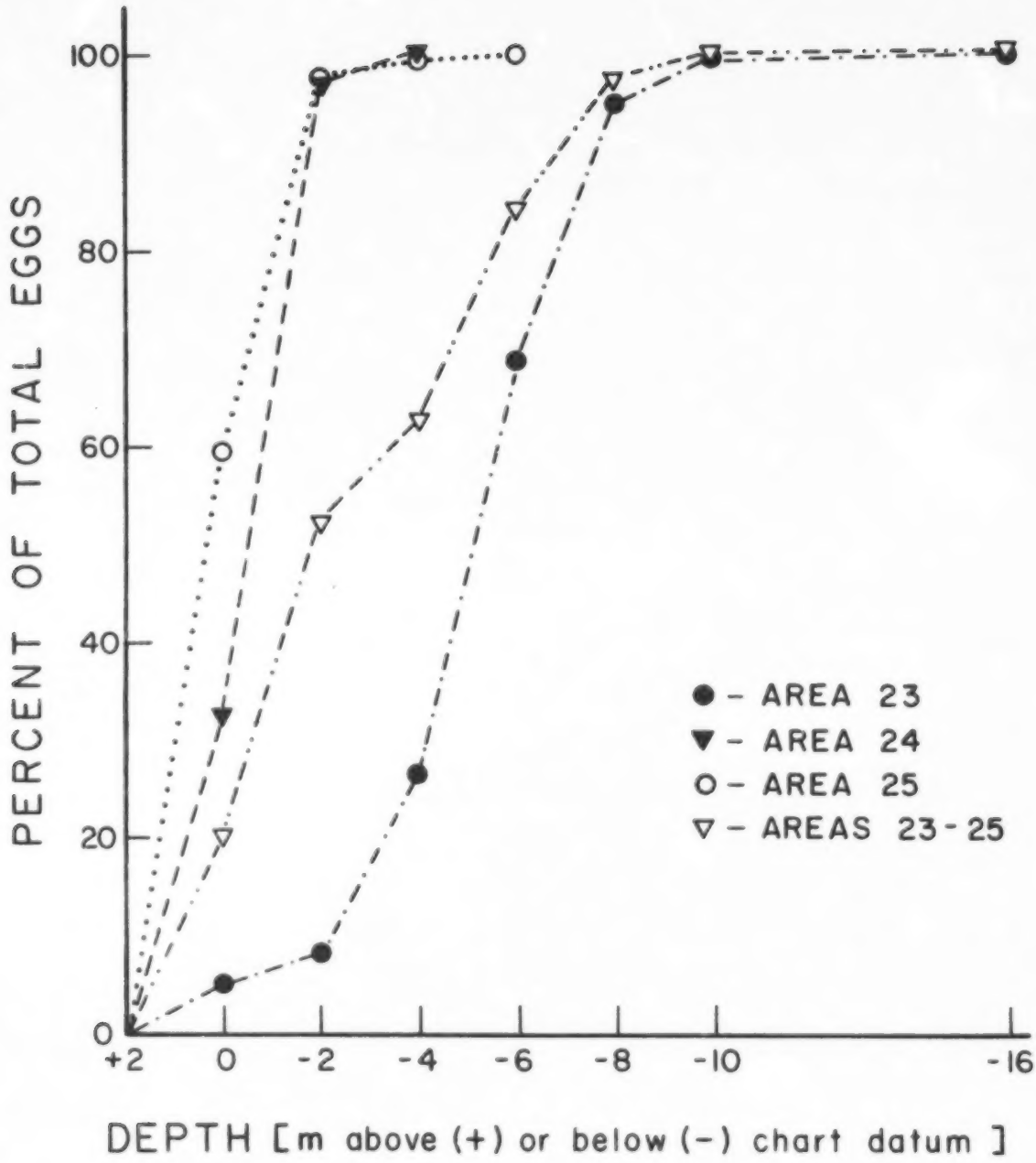


Fig. 19. Distribution of eggs by depth on the west coast of Vancouver Island in 1984.

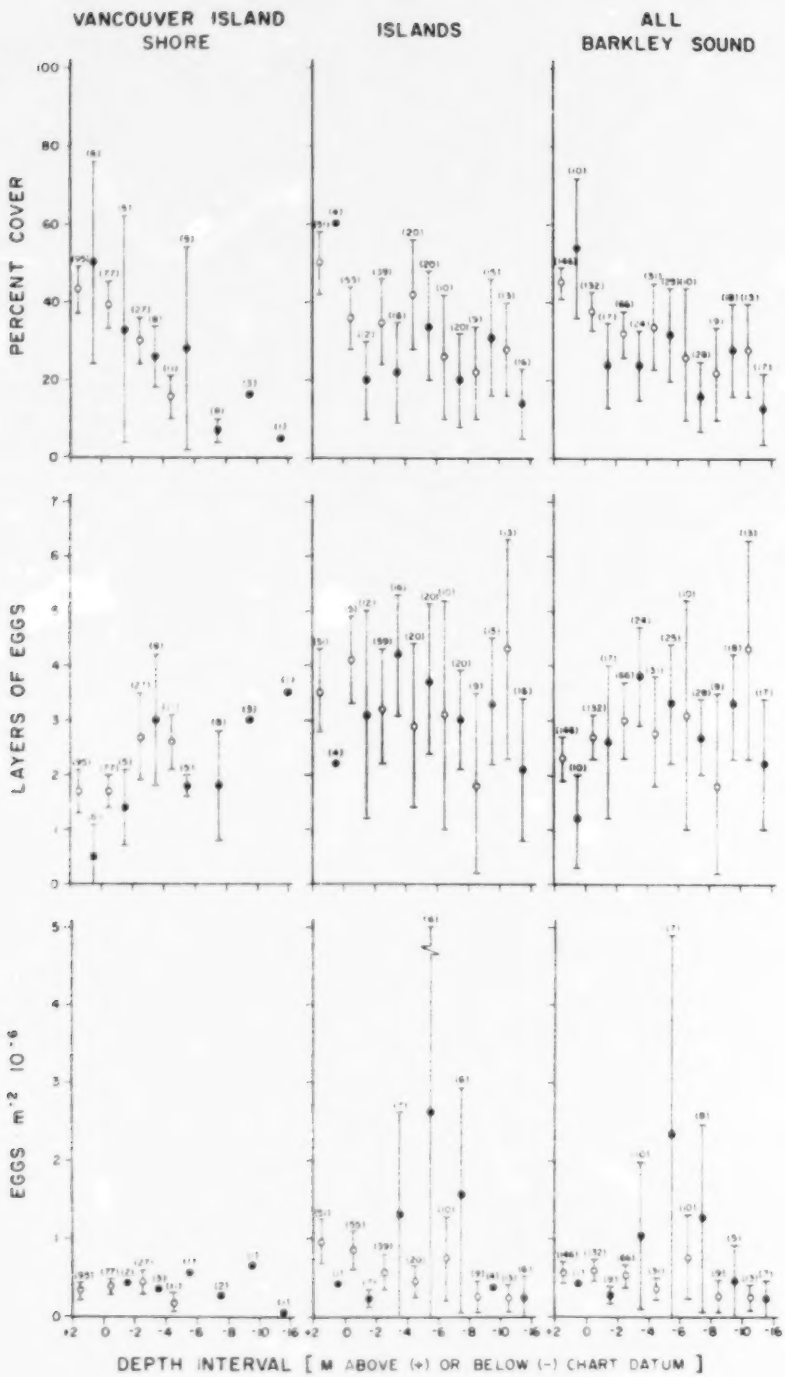


Fig. 20. Comparison of average percent cover, layers of eggs, and egg density (± 2SE) for herring spawns in Barkley Sound in 1982 (open circles) and 1984 (solid circles). Comparisons are for the gradually sloped Vancouver Island shoreline, the steeply sloped "Islands" shoreline, and for all of Barkley Sound.

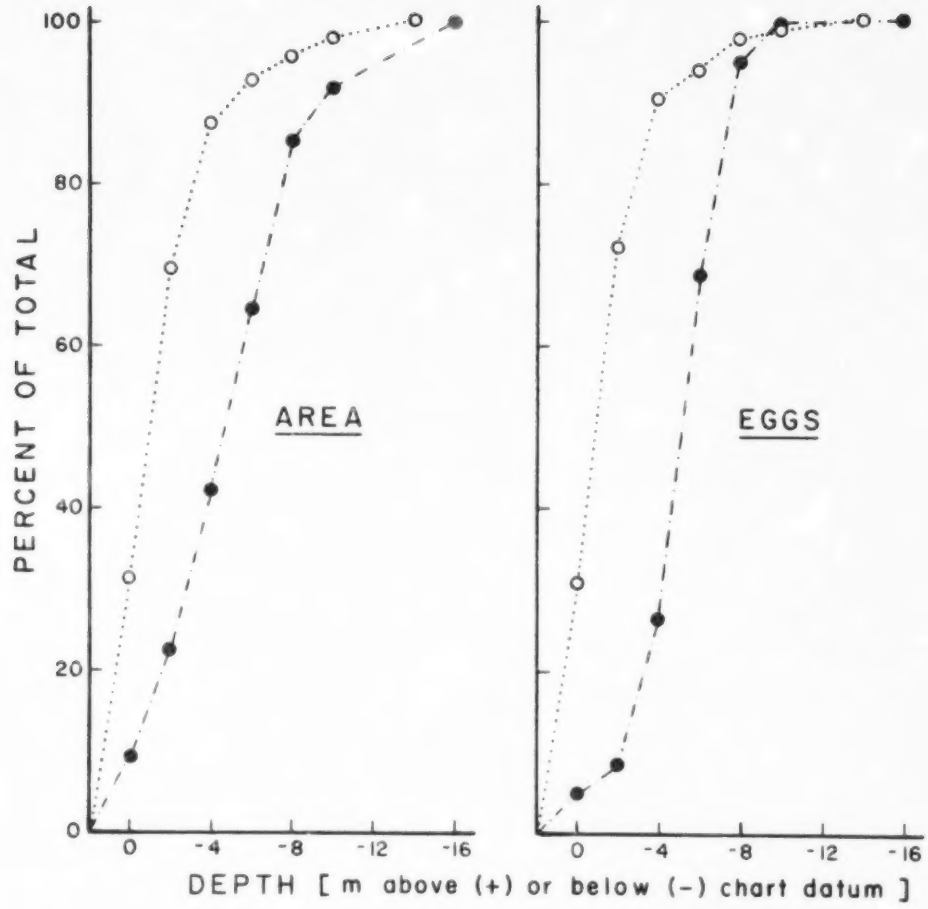


Fig. 21. Distribution of spawn area and number of eggs by depth in Barkley Sound in 1982 (open circles) and 1984 (solid circles).